Republic of Mozambique
Ministry of Land, Environment and Rural Development
Centre for the Sustainable Development of Coastal Zones

Economic Valuation of the mangroves ecosystem in the Limpopo River Estuary

2014

USAID FROM THE AMERICAN PEOPLE | SOUTHERN AFRICA
RESILIM : Resilience in the Limpopo River Basin Program

in support of

LIMCOM
LIMPOPO WATERCOURSE COMMISSION

ABOUT RESILIENCE IN THE LIMPOPO RIVER BASIN (RESILIM) PROGRAM

The Resilience in the Limpopo River Basin (RESILIM) Program is a five-year USAID-funded program committed to improve the lives of communities and the sustainability of ecosystems in the basin. The Limpopo River Basin stretches over the four countries of Botswana, Mozambique, South Africa and Zimbabwe where millions of people face water shortages, increased floods, and declines in crop productivity as climate change further stresses an already dry region. Transboundary cooperation between the four riparian countries and additional action is needed to prevent further degradation of critical river ecosystems that support livelihoods in the basin.

RESILIM's key counterpart and stakeholder is the Limpopo Watercourse Commission (LIMCOM), a sub-structure of the Southern Africa Development Community (SADC) and an advisory group to provide a forum for four riparian countries to collaborate, coordinate, and cooperate on Limpopo water-related challenges. In parallel to collaborating with LIMCOM, RESILIM provides support to the national-level institutions that comprise the transboundary organization.

RESILIM's mission is to improve the resilience of communities and ecosystems in the basin by working closely with various partners, such as the Centre for the Sustainable Development of Coastal Zones, to offer communities alternative livelihood options and ground-breaking natural resource management strategies.

ABOUT CENTRE FOR THE SUSTAINABLE DEVELOPMENT OF COASTAL ZONES

CDS Zonas Costeiras is a public institution with administrative autonomy, under Ministry of Land, Environmental and Rural Development. National headquarters is located at Xai-Xai Beach, and extends its activities throughout the country. It was created by decree 05/2003 of 18/02/2003. Government Gazette No. 7, 1st Grade, 2nd Supplement.

The CDS Zonas Costeiras aims to coordinate and promote research and dissemination, technical advice, training, development of pilot activities of management of the coastal environment, marine, and lacustrine to contribute to policy development and formulation legislation to promote the development of coastal zone of the country.

ACKNOWLEDGEMENTS

The authors of this article would like to thank all the individuals and organizations who contributed to the completion of work at all stages, particularly the MSc Victor Manuel Poio (Director of the CDS Zonas Coasteiras) and their technicians directly involved in the work (Henriques Balidy, Micah Mechisso Jacinta Laissone and Enera Patricio) for his work performance. Thanks also to all of its employees that gave the contribution at work including Alberto Matavel, Sergio Mbie, Lourdes Caetano, Silverio Chambule, Ganhane Juliet, Elsa Monjane, Tauria Wazir, Victorino Muguambe, Jacinta Laissone Sergio Solomon Mbié, Lourdes Caetano, Juliet Ganhane Raul Antonio and Mauricio Samuel.

Special thanks to the Government and local leadership, with emphasis to Mr. Ricardo Nhancuongo (Administrator of Xai-Xai District), the Head of the Administrative Office of Zongoene, Mr. Vasco Mula (Community Leader of Zongoene), Mr. Chicavele and Mrs. Rachel (Community Leaders of Chilaulene), Mr. João Nhanzimo (Secretary of Mahielene Community) and the Mahielene community in general.

Special thanks to the staff of Community Mangrove Nursery, with emphasis to Mr. Augostinho Nhanzimo and Carlos Macave (in charge of the team) and mangrove seeds collectors in Muntanhana (Ginoco Macaringue, Hortêncio Macaringue and Luis Nhaca).

Special thanks to the Pedagogical University, Delegation of Gaza, for their support in field work through their students involved in the collection of field data.

Finally, we address thanks to all entities that directly or indirectly contributed to this work and were not mentioned.

Technical Team of CDS Zonas Costeiras

1. Manuel Victor Poio
2. Henriques Jacinto Balidy
3. Micas Mechisso
4. Jacinta Laissone

Students of the Pedagogical University, Gaza Delegation

1. Ancha Amido Da Silva Inchiche
2. Cremildo Estvão Davane
3. Crescencio Felimone Mazangane
4. Elsa da Gloria Jesus Monjane
5. Farice Edson Mabote
6. Frederico Alexandre Issaca Laitela
7. Geralda Mupinga Bila
8. Majocote Pulquério Manuel Muchate
9. Nadia Fernando Mabote
10. Preselina Muacanane Tamele
11. Sónia Reginaldo Macaringue Mateve
12. Teodatina Celia Maria Bila

Permanent staff in the nursery

1. Agostinho Nhazimo
2. Antonio Domingos Milambo
3. Carlos Domingos Macave
4. Carolina Jorge Dzevo
5. Joao Samuel Simango
6. Rita Miguel Razo

Personal seeds collectors

1. Ginoco Macaringue
2. Hortêncio Macaringue
3. Luis Nhaca

ABOUT THE AUTHOR

Sennye Masike PhD is an Environmental Economist with extensive experience in ecosystem valuation, environmental modelling, climate change impact, vulnerability and adaptation assessment, GreenHouse Gas emissions and project appraisal. Over the year, he has consulted for various institutions both regionally and internationally. He is currently with EL Mondo (PTY) LTD as a senior researcher."

RECOMMENDED CITATION

Sennye Masike (2014) Economic Valuation of the Mangrove Ecosystem in the Limpopo River Estuary. For the USAID Southern Africa Resilience in the Limpopo River Basin (RESILIM) Program.

This report was compiled for the USAID Southern Africa Resilience in the Limpopo River Basin (RESILIM) Program and the Centre for Sustainable Development of Coastal Zones by Dr. Sennye Masike.

2014

Acronyms

CBA	Cost Benefit Analysis
CDS-CZ	Centre of Sustainable Development for Coastal Zones
CO_2	Carbon dioxide
CVM	Contingent Valuation Method
GDP	Gross domestic product
GWPSA	Global Water Partners for Southern Africa
HPM	Hedonic Pricing Method
IRR	Internal Rate of Return
IUCN	*International Union for Conservation of Nature*
IPCC	Intergovernment Panel on Climate Change
LPG	Liquid Petroleum Gas
NPV	Net Present Value
MZN	Mozambican Metical
NRA	Natural Resource Accounts
PES	Payment for ecosystem services
RESILIM	Resilience in the Limpopo River Basin
REDD+	Reducing Emission from Deforestation and Forest Degradation
SD	Standard Deviation
TCM	Travel Cost Method
TEV	Total Economic Value
TORs	Terms of Reference
WTP	Willingness to Pay
WWF	World Wildlife Funds
USAID	United States Agency for International Development

Definition of terms

Biodiversity is the degree of variation of life forms within a given landscape, ecosystem, biome or an entire planet

Climate change is defined by IPCC as a change in the state of the climate that can be identified using statistical tests by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer

Direct use is the value derived from actual use of a resource.

Greenhouse gas is defined as a gas that absorbs and emits radiation within the thermal infrared range.

Economic valuation is defined as assigning monetary value to non-marketed environmental goods and services or goods and services with incomplete markets

Ecosystem is the community of living organisms (plants, animals and microbes) in conjunction with the non-living components of their environment interacting as a system

Indirect use is the economic values that are associated with contribution of the ecosystem or natural resource to economic/household production processes

Mangroves are trees and shrubs that grow in saline coastal sediment habitats in the tropics and subtropics – mainly in 30° N and 30° S latitude

Protected Area is a clearly defined geographical space, recognized, dedicated and managed through legal or other effective means, to achieve the long term conservation of nature with associated ecosystems services and cultural values

Sustainability is simply defined as the state of continuity. It entails three (3) principles being economic, ecological and social sustainability.

Total economic value is the summation of the direct, indirect and non-use values.

Willingness to Pay is the maximum amount a person is prepared to pay, sacrifice or exchange in order to receive goods or services or to avoid a decline in service or undesired impact such as environmental pollution or degradation

Willingness to accept is the minimum amount an individual is prepared to receive to give up a good or accept an undesirable situation such as a decline in service or environmental degradation

Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt including areas of marine water the depth of which does not exceed six meters at low tide

Executive summary

The USAID-funded Resilience in the Limpopo Basin (RESILIM) Program aims to improve the trans-boundary management of the Limpopo River Basin to enhance community and ecosystem resilience to climate change impacts.

One of the ecosystems with a huge potential to significantly reduce community vulnerability and improve their resiliency to climate variability is mangrove ecosystems. Mangrove ecosystems are trees and shrubs that grow within the saline and brackish coastal environment. They are the second most productive ecosystem and globally support millions of communities residing in their proximity – such as the Zongoene community within the Limpopo Estuary. Comparable to other ecosystems, mangroves provide a diversity of products, functions and services that are of significant economic value to communities.

Paradoxically, even though mangrove ecosystems contribute significantly at both community and national levels, they have over the years experienced an accelerated deforestation mainly due to anthropogenic factors. One of the underlying drivers of mangrove depletion and degradation is the lack of information on their economic value. Even though communities have mental knowledge of the crucial role played by mangroves, the ecosystem lacks quantified economic values. Thus, the economic values have only been conceptualized by communities and decision makers. In order to curb widespread mangrove depletion in the Limpopo Estuary, there is need to undertake an economic valuation. This underpins the objective of this assignment.

Incidentally, through the Limpopo mangroves valuation exercise, this assignment aims at bridging the information gap. It is envisaged that valuing mangroves would facilitate integration of mangrove values into economic decision making at all levels (household, district and national level) and enhance sustainable decision making for mangrove utilization.

Approaches and methods

In order to achieve the objectives of the assignment (Mangrove ecosystem valuation and evaluation of the mangroves reforestation sustainability project) the following approaches and methods were used:

- Total economic value: the concept acknowledges that mangrove ecosystems are multifunctional and have use and non-use values. Therefore, the economic value of mangroves includes direct use values, indirect use values and non-use values - mainly options and existence values.
- Market price: this valuation approach has been devised from the realization that some mangrove products (e.g. timber, fuel wood etc.) are marketed and therefore have a price. The market price can be used to inform the economic value of mangroves arising from direct utilization of mangrove products.
- Surrogate market price: this approach concedes that though some mangrove products directly used are not marketed, they do however have close substitutes available from other production processes (LPG and fuel wood, modern medicine and traditional medicine). As the substitutes perform the same roles via different production processes, it is logical for their values to be equivalent.

- Production Function Methods: these are valuation methods that infer to the value of ecosystems by determining their contribution in production of marketed goods and services.
- Replacement/mitigation costs: the amount of money an individual incurs in replacing damage or mitigating an impact can be used as a proxy for their willingness to pay to protect/conserve that particular variable.
- Contingent valuation method: it is a direct and hypothetical valuation technique that infers to the value of an ecosystem (use and non-use values) through the use of questionnaires.
- Cost benefit analysis: this is an appraisal technique that uses money as a yardstick to assess the viability of a proposed project. In this assignment, the method was used to determine the economic sustainability of reforesting the degraded mangroves.
- Institutional capacity scorecard: a scorecard is a tool that is used to assess the performance of an entity over a set of criteria and targets. It is made up of aspects and components with scores. This method was used to assess the capacity of CDS in implementing the project without external support with an emphasis on human capital.
- Consultation and field visits: these methods were used in valuation and assessment of the ecological sustainability of the mangrove reforestation project.

Key results/findings of the analysis

Mangrove ecological structure

Limpopo mangroves have five (5) tree species mainly *Avicennia marina* (Grey Mangrove or White Mangrove), *Rhizophora mucronata* (Loop-root Mangrove, Red Mangrove or Asiatic Mangrove), *Bruguiera gymnorrhiza* (Black Mangrove), *Ceriops tagal* (Indian Mangrove), *and Xylocarpus granatum* (Cannonball Mangrove or Cedar Mangrove). The dominant species has been identified as *Avicennia marina* (Grey Mangrove or White Mangrove) constituting approximately 92.5 per cent (Silva *et al,* 2014). Key environmental factors that influence mangroves in their ecological functioning include; temperature, rainfall, tides, and rivers. Mangroves are classified as one of the most productive ecosystems with an estimated primary productivity of 2 grams m^{-2} day^{-1}. Furthermore, it is reported that the Limpopo mangroves have the highest biomass estimated at 207 mg ha^{-1} aboveground and a height of above 5 meters. Additionally, it is reported that belowground biomass constitutes more than 75 per cent of total biomass. Thus, mangroves are a major source of carbon and potentially provide mitigation measures against climate change impacts. In terms of the fauna, it is reported that there are over 120 fish species and a great diversity of Crustaceans. Some of the fish species that have been identified include Carangidae, Lutjanidae, Sciarenidae, Cerranidae, and Sparidae. In addition, a survey by Silva et al (2014) revealed that there are a variety of crabs that reside in the Limpopo mangroves such as shore crabs, burrowing crabs, sand-bubbler crabs, shrimps and prawns and mud creepers. The mangrove flora and fauna have various ecological functions that contribute to its productivity. For instance, the crustaceans break down litter and absorb excessive metals and nutrients which could otherwise upset the ecological balance. In turn some of the fauna are a source of food for various types of fish. The ecological relationship between mangrove flora and fauna is closely intertwined through an ecosystem's food web.

Mangrove ecosystem ecological functions include the provision of habitat and spawning grounds for juvenile fish as well as breeding grounds, protective functions against coastal erosion include the dissipation of wave energy and control of flooding and storms (high tidal waves), sedimentation load regulation and thus protection of Sea grass and corals reefs, significant contributions to offshore commercial fishing, the control of salty water intrusion into agricultural land uses, a net carbon sink and significant role in carbon sequestration, amongst others. Due to their multi-functionality it is undisputed that the economic values of mangrove ecosystems would be astronomically high as reported in other studies.

Economic valuation

The economic value of mangrove ecosystems was estimated based on their direct, indirect and non-use values. The direct uses comprise the harvesting of mangrove products mainly fuel wood, timber (construction material), fish, crustaceans, and traditional medicine. Amongst these products, crustaceans, fish and fuel wood were indicated to be the most important in communities' livelihoods. Market price based approaches were used to infer the value of these products. The table below depicts the economic value of the identified products based on the quantity harvested on an annual basis.

Product	Economic value (millions MZN)
Apiculture	0.05
Crustaceans	128
Fish	183
Fuel wood	0.37
Timber	44
Traditional medicine	0.76
Total direct use value	**357**

Indirect values are the economic values that are associated with the contribution of the mangrove ecosystem to production processes. In this case the mangrove products are not harvested but its attributes positively influence the production of goods and services. For instance, through its function of controlling floods, it regulates salty water from intruding into agricultural fields and thus positively impacts upon agricultural productivity. Deriving the indirect use value was based on production function techniques and replacement costs methods. However, due to limited data, some of the vital economic values of mangroves were not estimated. The table below depicts the indirect economic value of mangrove ecosystems.

Mangrove function	Economic value (Million MZN)
Offshore fishery	29.5
Carbon sink	38.1
Total indirect use value	**67.6**

Thus, the total use value of mangroves was estimated at MZN 424 million annually. However, this excludes the contribution to agriculture and sedimentation control which protects coral reefs. As coral reefs and Sea grass contribute to the commercial fishery sector, the value of this protective function is partially included in the estimations.

In addition to the direct and indirect use value of the mangroves, it is postulated that individuals also have a willingness to pay (WTP) for not using the mangrove ecosystem. These values are classified as option and existence values. Based on the CVM and the corresponding survey, households revealed a positive WTP for mangrove conservation and reforestation programs. Respondents indicated their WTP through either cash or labor. As labor has a value, measured in terms of value of time, the indicated number of days participating in mangrove reforestation was converted into cash (money). Consequently, the WTP for cash and labor was estimated at MZN 70 and MZN 650 per month respectively. Obviously, there is a huge difference between WTP in cash and labor. This is mainly due to the psychological effect of the value of money, which means that labor is valued low, relative to paying in cash.

Mangrove reforestation project sustainability

Mangroves reforestation project is an ongoing project initiated by CDS in 2010 and has currently covered 30 hectares. This project is implemented on mangroves that have been deforested by floods that occurred in 2000. The sustainability of the project was estimated based on economic, social and ecological aspects. Economically, CBA was used to estimate the NPV and IRR. Based on a 50 year period, the average lifespan of the mangroves based on Alongi (2002), the past cost of reforestation and economic benefits of mangroves from the assignment, NPV and IRR were estimated at MZN 990 million and 236 per cent, respectively. This depicts a high economically sustainable project. However, it is important to emphasize that this finding differs from typical afforestation projects where the cost is incurred now and the benefits much later. In terms of financing sustainability the project was assessed to be financially unsustainable. Even though the project has a healthy mix of financing sources, there are no measures in place to internally generate revenue. Therefore, there is a need to devise measures for internal revenue generation. Institutionally, CDS scored an impressive score of 93% in terms of capability to solely implement the project without the support of external expertise. The institute is highly human resourced. In terms of monitoring and law enforcement, the score was estimated at 47 per cent. Therefore, the seedlings and new established mangroves will be highly exposed to unsustainable practices as law enforcement and monitoring is sorely lacking.

The mangroves environment has not been heavily degraded. This is testimony to the fact that the survival rate of the seedlings is over 70 per cent. Paradoxically, past practices such as charcoal production activities could have positively affected the soil properties. There is an increase in charcoal content in the soils which has affected pH, nitrogen and organic content which are all beneficial for the growth of seedlings. On the other hand, it is reported that porosity of the charcoal provides a recalcitrant which is food source for microbes and provides a favorable habitat for soil microflora which thus alters the predation rates by soil micro fauna (Kolb et al, 2009). It is possibly for these reasons that there is a prolific population of crabs in the project sites. It is reported that prior to the innovative reed stem mitigation measure to reduce consumption of the seedling by crabs, the survival rate of the seedling was approximately 20 per cent.

Conclusions

The following conclusion can be drawn from the assignment:-

- Mangroves in the Limpopo estuary are multifunctional providing multiple products, functions and services that are of high ecological and economical value. They support the majority of local communities through varies functions and also provide a vital source of food and energy.
- These products, functions and services vary both spatially and temporally. For instance, the carbon sink function is beneficial globally while regulation of the microclimate acts at a local to regional scale. Temporally, the functions also vary from seasonal to yearly. For instance, the protective function against storms and high tidal waves is seasonal.
- The economic value of mangroves is estimated at MZN 424 million and the direct use value constitutes a high proportion of this and is estimated at MZN 347 million.
- This has sustainability implications and shows that there is a high direct use value of mangrove products and less use of functions and services offered by the mangroves themselves.
- The majority of community members (80 per cent) in the proximity of the Limpopo Estuary mangroves indicated that they would be WTP for its conservation through reforestation.
- Of those who revealed that they would be WTP for mangrove reforestation project, 84 per cent indicated that they would be WTP through labor while 16 per cent indicated that they would prefer paying in cash.
- For those WTP through labor, their WTP based on value of labor was estimated at MZN 650 per month (10 working days) while those who indicated cash payments their WTP was estimated at MNZ 70 per month.
- Assessment of the economic sustainability of reforestation project revealed a high positive NPV and IRR of MZN 599 million and 236 per cent for a timeframe of 50 years.
- In terms of funding mechanisms, the project has a solid mixed funding mechanism. However, the project lacked an internal funding mechanism in terms of tools for revenue generation.
- There is a dearth of policies and no legal framework to enhance the project by generating revenue for conservation activities such as monitoring.
- Socially, the project was sustainable based on the results from an institutional capacity scorecard.
- Non-anthropogenic activities particularly floods have catastrophic impacts on mangroves and could worsen with climate change.
- In terms of monitoring and law enforcement, the score was estimated at 47 per cent implying that the new established plantation could be exposed to unsustainable practices in the future. Hence, monitoring needs to be improved.

Recommendations

Based on the findings of this assignment, the following recommendations were made:-

- Efforts must be put in place to ensure that members of the community maximize the benefits from indirect uses of the mangroves. This will ensure that the sustainability of mangroves utilization is enhanced as indirect benefits do not result in harvesting of mangrove products. This can be done through improving aquaculture, apiculture, ecotourism and agriculture practices.
- Analysis reveals that the reforestation project has virtually no mechanism for the generation of internal revenue. This basically implies that if the funders pull out, the project could be seriously affected. It is thus important that for project continuity, tools for revenue generation be designed and implemented. One of the important ways in which mangroves can generate revenue for monitoring and law enforcement is through Payment for Ecosystem Services. There are many forms of Payment for Ecosystem Services such as charging for using products, the sale of sustainably harvested products and timber, REDD+ programs. It is thus important that Payments for Ecosystem Services are comprehensively designed and implemented for monitoring and enforcement purposes. This thus calls for further studies for development of PES framework and guidelines for implementation PES best model.
- Monitoring and law enforcement is found to be lacking when it comes to the utilization of mangrove products. It is thus pertinent that efforts are geared towards improving monitoring and law enforcement.
- One way to improve monitoring and management of the mangrove resource is through co-management where members of the community are actively involved in mangrove management. Co-management is a double-edge sword in terms of benefits as the community members will be part of the decision making process and will also realize improved benefits and household income from better managed mangroves.
- It is recommended that in-depth assessment be undertaken to identify the optimal co-management model that can be implemented for management of Limpopo mangrove ecosystem and guidelines be developed to guide its implementation. The guidelines should elaborate on roles and responsibilities of each party, costs and benefits sharing formula.
- Mangroves have considerable potential for eco-tourism activities which currently are non-existent. It is thus important for communities to be encouraged to venture into these activities. Thus, furthermore work is required on assessment of potential ecotourism projects, their feasibility, viability and development of management plans (entailing business plans). Additionally, it is pertinent that assessment of current climate in terms of policies and legal framework to support such business ventures be undertaken.
- There is a need to design and implement economic activities and policy frameworks for diversifying pressure away from the mangroves. Potential policies include subsidies on natural gas. Therefore, there is need to undertake a thorough assessment on economic activities and supporting policies that can be implemented with emphasis on Cost Benefit Analysis.
- Though members of the communities are highly knowledgeable about the economic benefits of the mangroves, they lack information on the actual values and economic contribution of mangroves to their household income. Therefore efforts must be geared towards information dissemination on the total economic value of mangroves and the contribution they make to household income.

- Floods have disastrous impacts on mangrove ecosystems as evident from the year 2000 floods. It is thus recommended that an integrated Limpopo river basin management system is developed in cooperation with the Limpopo Riparian states/countries. This management system should develop guidelines on dams and flood control in the Limpopo River.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF PICTURES

LIST OF MAPS

1. Introduction

This assignment is part of the larger project titled "Resilience in the Limpopo Basin Program" funded by USAID/Southern Africa. Its overall goal is improving trans-boundary management of the Limpopo River Basin to enhance community and ecosystem resilience to climate change impacts. The program is anchored around three interrelated objectives mainly to:

1. Reduce climate vulnerability by promoting the adoption of science-based adaptation strategies for integrated, trans-boundary water resource management
2. Conserve biodiversity and sustainably manage high-priority ecosystems
3. Build the capacity of stakeholders to sustainably manage water and ecosystems.

Conserving biodiversity and sustainably managing high-priority ecosystems promotes conservation of biodiversity, ecosystem resilience, and sound natural resource management within key biodiversity areas in the Basin. Thus, ecosystems and their services are at the forefront of the program. Ecosystem services are simply defined as the benefits to human society from direct and indirect utilization of natural resources. Services derived from ecosystems such as mangroves can be divided into four main groups being:

a. Provision of services: ecosystems provide various products which are directly used by economic agents such as food, water, timber, pharmaceutical, traditional medicine etc.
b. Regulation services: some of the services provided by ecosystems include climate control, waste decomposition and detoxification, water purification, soil erosion prevention *etc.*
c. Support services: these include nutrients dispersal and recycling, primary production.
d. Cultural and educational services: cultural service include cultural intellectual and spiritual inspiration, scientific discovery etc.

Based on the wide range of ecosystem services as highlighted above, it is apparent that societies are entirely dependent on ecosystems for provision of factors of production, life support services as well as waste sink functions. One of the ecosystems supporting communities and providing a wide range of services is the mangrove. A Mangrove ecosystem comprises of trees and shrubs of the *genera (Rhizophora, Brugiera, Sonneratia and Avicennia*) that grow within saline and/or brackish coastal environments. Due to the deposition of sediments of high organic content, they are arguably the second most productive ecosystems in the world (Salem and Mercer, 2012). Critically, coastal communities are highly dependent on mangroves ecosystems directly and indirectly for both subsistence and commercial purposes. It is thus the case with the Zongoene communities that are residing within the proximity of the Limpopo River Mouth.

Paradoxically, though mangroves are of high economic significance to communities and contribute immensely to the country's national income, they have over the years been radically degraded and deforested. Activities that have significantly contributed to mangrove deforestation and degradation include:

- Conversion to salt evaporation ponds,
- Aquaculture,
- Housing development,
- Illegal dumping of waste,
- Golf courses and farms.

One of the underlying factors for mangroves degradation is missing markets for the products and functions. This results in an information gap on mangroves economic value. Perceptibly, the lack of information on mangrove value culminates in mental undervaluation of mangroves and unsustainable consumption. Consequently, this assignment aims at bridging the information gap by valuing the Limpopo mangroves. It is envisaged that valuing the Limpopo mangroves will facilitate the integration of ecosystem economic values into economic decision making at all levels (household, district and national level) and so facilitate sustainable utilization.

1.1 Objectives of the assignment and tasks

The main objective of this assignment is to elicit the economic value of the Limpopo Estuary mangrove ecosystem in Mozambique. Essentially, this will involve an in-depth understanding of the mangroves ecological structure (species assemblages, interaction and functional roles), key environmental factors that influence mangroves functionality, and the spatial-temporal characterization (and/or description) of mangroves ecosystem services. Consequently, this ecological analysis will create a platform for mangroves valuation in the Limpopo Estuary. Economic valuation is essentially a decision making tool. It presents clear and logical information on values and correspondingly costs to be incurred in the event of ecosystem degradation at both local and national levels. Additionally, such valuation exercises provide a justification for mangroves reforestation as well as an assessment of their overall sustainability within the Limpopo Estuary.

Subsequently, it is expected that the valuation exercise will demonstrate the economic values of mangrove ecosystems at the national level. Furthermore, it is expected that it will aid in better mainstreaming ecosystem services into sectorial and national planning. Importantly, it is expected that the results will justify implementation of diversification projects to alleviate pressure on the mangrove ecosystem.

The assignment has four (4) thematic areas as highlighted logically below:

a. Mangroves ecological structure

- Identification of the ecosystem service providers- species or populations that provide specific ecosystem services and characterization of their functional roles and relationship and determining abiotic environment.
- Determination of community structure aspects that influence how ecosystem services providers function in their natural landscape
- Assessment of key environmental factors influencing the provision of services.
- Measurement of the spatial and temporal scales of ecosystems services providers.

b. Mangrove economic valuation

- Determine the value of mangrove ecosystems (and the estuary) in terms of direct and indirect value.

c. Development of guidelines for mangroves ecosystem valuation

- Develop and submit clear guidelines on the methods used in valuation and pricing.

d. Sustainability of mangrove reforestation

- To assess the sustainability of mangrove reforestation activities in the Limpopo river estuary.

2. Mangroves ecological structure

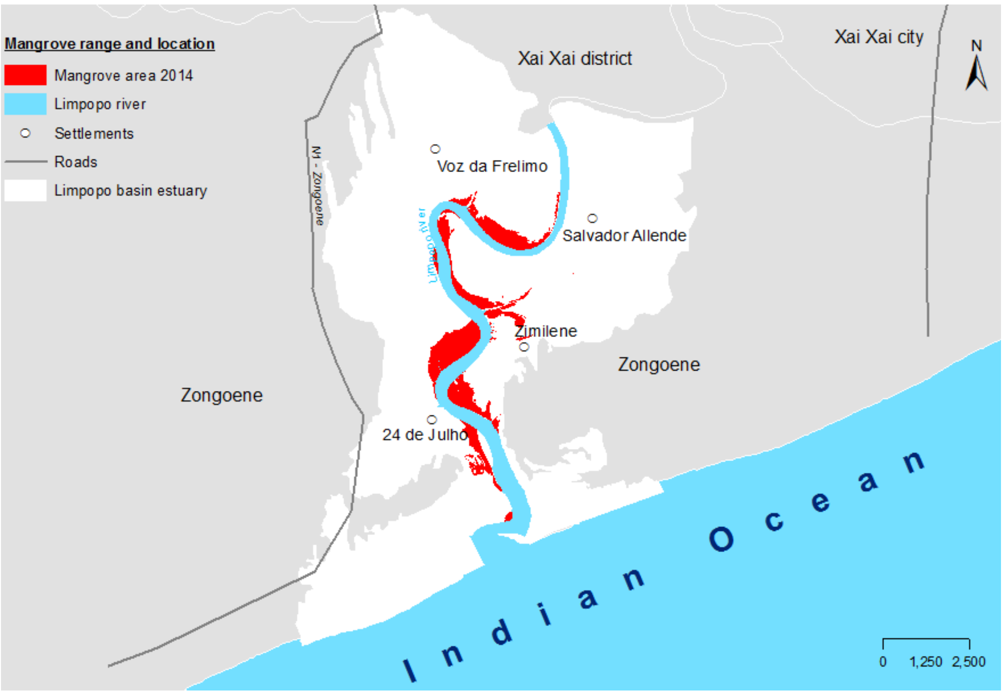
2.1 Introduction

This section of the report details the ecological structure of the Limpopo Estuary mangroves. Issues that are discussed include species composition of both flora and fauna in the mangrove ecosystem. Additionally, the section discusses the ecological relationship between the species. Ecosystems are influenced by various factors such as temperature, rainfall and tides and floods. Lastly, as mangrove ecosystems support thousands of people residing in their proximity it is also fitting and appropriate that both the temporal and spatial influence of the mangroves be assessed. Consequently, the section is of paramount importance as it contributes to valuation of the Limpopo estuary mangroves.

2.2 Mangrove species composition and structure

Mangroves are defined as trees and shrubs of the genera (*Rhizophora, Brugiera, Sonneratia and Avicennia*) that grow within the intertidal zone along tropical and subtropical coasts (Fatoyinbo et al, 2008; Taylor et al, 2003). Thus, they are highly tolerant to a salty and brackish environment. On the other hand, they are highly intolerant to cold climates and hence restricted within the tropical and subtropical zones between approximately 30° N and 30° S latitude (Giri et al, 2010). The development of mangrove ecosystem is highly influenced by climate (temperature), rainfall, tides, waves and rivers, key environmental factors that influence the deposition of fine-grained alluvium which in turn creates an optimal condition for mangrove development. According to Alongi (2002) "Waves, tides, rivers and rainfall affect water circulation by generating turbulence, advective and longitudinal mixing and trapping coastal water, influencing the rate of erosion and deposition of sediments on which mangroves grow". Thus primary environmental factors that influence mangroves development are temperature, rainfall, tides, waves and rivers.

Globally, over 70 mangroves species have been identified while in Mozambique, it is reported that there are nine (9) species of mangroves. These species include *Rhizophora mucronata (*Loop-root Mangrove, Red Mangrove or Asiatic Mangrove*), Bruguiera gymnorrhiza* (Black Mangrove)*, Avicennia marina* (Grey Mangrove or White Mangrove)*, Ceriops tagal* (Indian Mangrove)*, Sonneratia alba* (Mangrove Apple) *and Xilocarpus granatum* (Cannonball Mangrove or Cedar Mangrove) (MICOA, 2006; Barbosa *et al*, 2001). Map 1 depicts spatial distribution of the Limpopo Mangrove ecosystem and settlements in proximity. Table 1 depicts the mangroves species in the Limpopo and their composition as surveyed by Silva *et al* (2014). According to Sitoe et al (2014) mangroves in the Limpopo Estuary are relatively tall with a height of approximately 27 m and above ground tree biomass of 207 mg ha^{-1}.



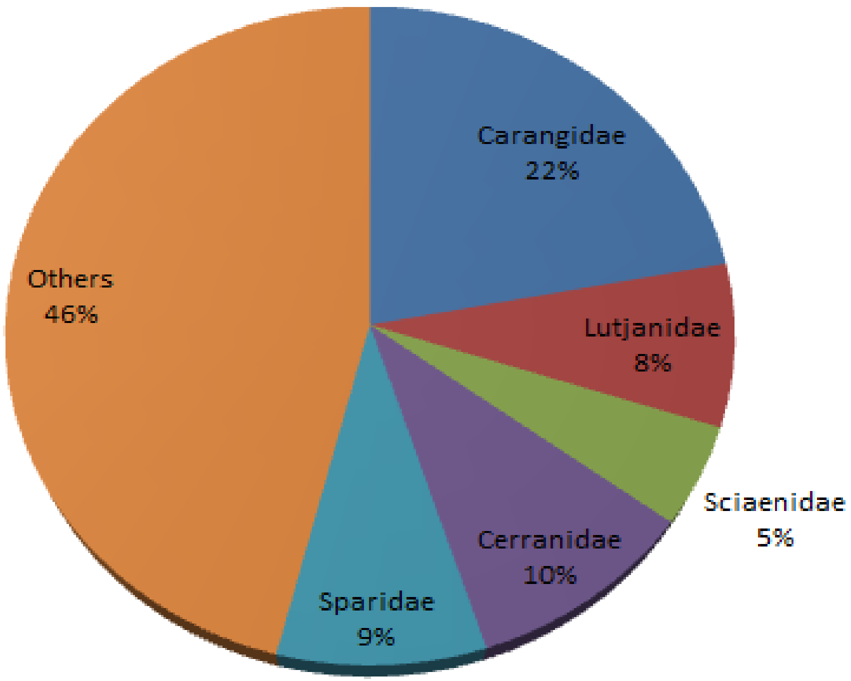
Map 1: Spatial distribution of the Limpopo Mangroves

Source: Da Silva (2014)

Table 1: Limpopo Mangrove species and prevalence rate

Species	Prevalence rate (%)
Avicennia marina (Grey or White Mangrove)	92.5
Rhizophora mucronata (Loop-root mangrove, Red Mangrove or Asiatic Mangrove)	6
Bruguiera gymnorrhiza (Black Mangrove)	1
Ceriops tagal (Indian Mangrove)	0.3
Xylocarpus granatum (Cannonball Mangrove or Cedar Mangrove)	0.2

It is reported that mangrove ecosystem is characterized by high primary productivity of 2.5 g carbon m^2/day making them the most productive aquatic ecosystem (Fatoyinbo et al, 2008). The high primary productivity of the mangroves makes them highly diverse in terms of fauna. Silva *et al.,* (2014) estimates that over 120 species of fish belonging to 52 families have been recorded in the Limpopo Estuary. The dominant fish species according to Silva et al (2014) are as depicted in figure 1 below.



Picture 1: Projected fish population from catch

Source: Silva et al (2014)

Other fauna species that reside within the Limpopo mangroves include crabs and molluscs and shrimps. Table 2 below depicts types of crustaceans and *molluscs* occurring in the Limpopo mangrove and their ecological function.

Table 2: *Crustaceans and molluscs known to occur in the Limpopo Estuary.*

Common Name	Scientific Name	Functions of the species
	Matuta lunaris	• inhabit sand flats bordering mangroves • omnivorous, eats other crabs, flat fish, shell fish and worms
Shore crab	*Carcinus maenas*	• invasive species for NE Atlantic & Baltic sea • high coloration variability; green-brown-grey-red • wide salinity tolerance (4 – 52%), but highly sensitive to low salinity and hypoxia • predator feeding on - molluscs (oyster, clams, mussels), polychaetes, crustaceans and fish • source of protein for humans (food) • through predation can have substantial impact on commercial and recreational fishing
burrowing crabs	*Cardisoma carnifex*	• with *Sesarma* spp, they are the most common mangrove crabs • inhabit intertidal and mangroves zones • As the name suggests they burrow the substrate • herbivorous, feeding mainly on fresh leaf litter (*Bruguiera gymnorrhiza, Avicennia marina, Sonneratia alba, Rhizophora mucronata & Ceriops tagal* • play an important ecological function in mangrove environments- litter clean-up & nutrient cycling (can consume upto80% of fresh leaf litter)

Sand-bubbler crab	*Dotilla fenestrata*	• small crab species (1cm wide) that live in burrows on the sand • inhabits sand flats adjacent to mangroves • detritivores and highly abundant
Hermit crabs	*Coenobia* spp *Clibanarius* spp	• omnivorous - feeds on small animals & vegetation • known to scavenge on carrion • have a soft shell and for safety takeover empty gastropods shells • 16 species identified in Quirimba Archipelago (Mozambique)
Fiddler crab	*Uca* spp	• inhabit mangroves, muddy sand beaches & swamps • males exhibit sexual dimorphism in claws (one claw is disproportionately large) • generalist detritivores (vegetable matter, rotting organic matter, algae, microbes, fungus) • ecological significance – sifting through the substrate they clean-up and aerate the systems, hence prevent anaerobic conditions • Ecological significance – leaf litter clean-up and nutrient cycling
Mangrove/mud crab /giant mud crabs	*Scylla serrata*	• mangrove residents and can reach 3.5kg • high ecological plasticity and adaptability • rapid growth and can be cannibalistic • diet – small fish, vegetable matter and aquatic invertebrates (e.g. molluscs and smaller crab species) • highly sought after for food (fetch high price in fish markets)
Marsh cabs,	*Sesarma spp*	• similar to burrowing crabs, *Cardisoma carnifex*
Rock oysters	*Saccostrea cucullata*	• inhabits rocky habitats along shores • in mangroves it attaches to tree branches and roots • filter feeder – plankton • accumulates metals (form diet) in its tissues and thus can be used as a bio-indicator
Shrimp & prawns		• many species in mangroves and freshwater • free swimming decapods crustaceans • important food source for large animals (birds, fish and crabs) • commonly of significant commercial value as food
Mud creepers	*Terebralia palustris*	• Important sources of protein for people (food)
Mud whelk	*Cerithidea decollta*	
Strombus spp	*Strombus spp*	
Mussels	*Perna*	
Limpets	*Patellas spp*	
Barnacles	*Balanus amphitrite*	• grow on trunks of mangrove trees (mangrove roots provide habitat)
Starfish		
Sponges		

Source: UNEP/FAO/PAP (1998), Taylor et al (2003), de Grave & Barnes (2001)

2.3 Ecological relationship between mangrove species

As highlighted in table 2 above, mangroves flora and fauna have varied and diverse ecological functions with each species engaged in vital functions for the overall functionality of the mangroves. Some species such as burrowing crabs play a vital ecological role through litter clean-up and nutrient cycling (can consume up to 80% of fresh leaf litter). It is common knowledge that mangroves breakdown harmful substances and also absorb excessive nutrients which could otherwise upset the marine ecosystem. This function is partially attributed burrowing crabs and rock oysters. Consequently, the relationship between the mangroves species (flora and fauna) is closely inter-connected through complex food chains (figure 1).

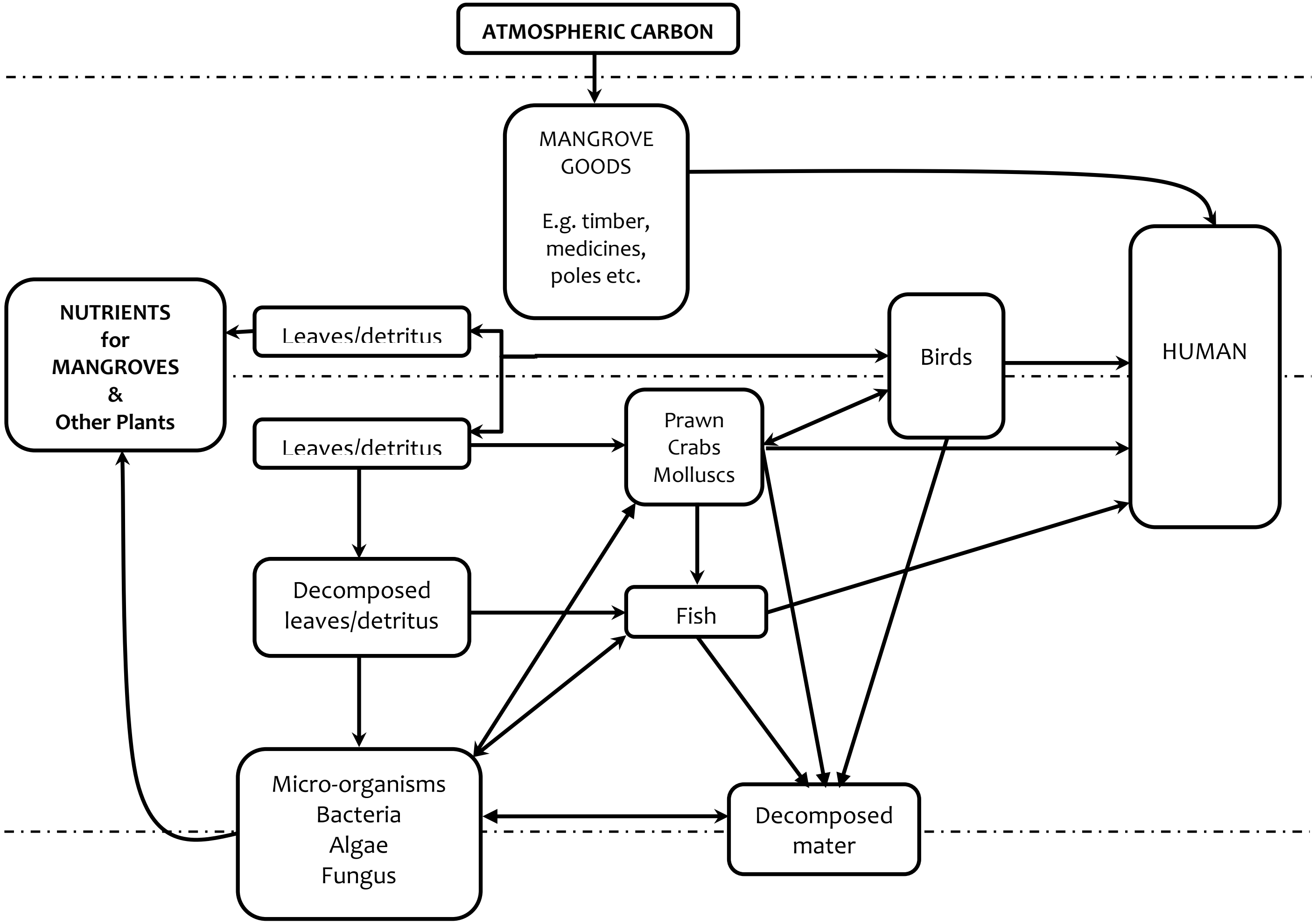


Figure 1: ***Schematic representation of energy transfer linkages (food chain/web) of Limpopo Estuary***

2.4 Ecological Function

The physical structure and physiological adaptation of mangroves allows them to grow in very harsh conditions. They are characterized by high resistance to salty water, enabling them to grow in brackish and full salinity seawater, and their root structure enables them to root in mud or sand. It is these properties that make them adaptable to the continuous force of waves and tides. They act as coastal buffer zones, by accumulating sediment and protecting coastal areas from wave action, erosion, storms and tidal forces (Fatoyinbo et al, 2008). The extensive and often exposed root system acts to dampen the energy of tides and waves and freshwater inflow. In so doing, they as well protect the upper stream from impacts of sea tides and waves. It is from these adaptations that mangrove forests are best developed and occur around river mouths where they also play an important role in trapping sediments washed down in river discharge that would otherwise be washed out to sea (Samoilys *et al*, 2013). Thus, mangroves act to stabilize the sea-freshwater interface mainly in terms of salinity and dual opposing water force, so creating a localized closed system that supports a wide diversity of biological species.

High primary production is characteristic of mangrove ecosystems that has been estimated at two (2) tons/ha/year for East African mangroves (Cannicci et al, 2009). This high level of productivity is attributed to the fact that they receive nutrients from both sea and land (Taylor et al, 2003). According to Taylor et al (2003), detritus is the primary energy source in tropical estuaries and mangrove tree species are the major producer of this organic litter (Taylor et al, 2003). Therefore, they play a primary function in energy and nutrient transfer and/or recycling in closed estuaries as they are able to absorb nutrients from both marine and freshwater which they convert and make available to a wide range of primary consumers that cascades up the trophic structure in the ecosystem.

Mangroves are known to accomplish crucial ecosystem functions and services (Cannicci et al, 2009). They also provide a wide range of ecosystem goods and services, such as nursery areas for fish, prawns and crabs which in turn provide communities with a variety of food, timber and chemicals, and protect coasts from catastrophic events and erosion (Cannicci et al, 2009; Samoilys et al, 2008; Taylor et al, 2003). Mangrove timber is used locally in construction and for fuel, with the ecosystem supporting artisanal fishing, subsistence fishing, as well as providing resources for both the livestock and tourism sectors (Taylor et al, 2003). Apart from their high primary productivity, they are as well an important source of carbon sequestration and storage, and consequently climate change mitigation. They are important barriers for mitigating coastal disturbances (e.g. tsunamis, storms and others) and provide habitat for over 1300 animal species and are one of the most productive ecosystems in the world (Fatoyinbo et al, 2008).

Although mangrove estuaries have relatively narrow tree diversity, they carry a wide biological species diversity especially relative to other ecosystem of semi-arid environs of Southern Africa. Both terrestrial and aquatic biodiversity within mangroves are high conferring a significant economic role to the systems (Taylor et al, 2003), i.e. mariculture (prawns & crabs), aquaculture, timber and charcoal, and high potential for recreational tourism (sport fishing, game viewing and other non-consumptive uses).

2.5 Spatial and temporal scale of mangrove ecosystem functions and services

Mangrove ecosystems provide vital ecological and economic functions and services which are of particular importance to the community residing within the proximity of the mangroves. Additionally, some of the functions and services also benefit the regional and global communities. For instance, the function of mangroves as a carbon sink is of global importance as the global community benefit from the climate change mitigation and reduced costs of climate change. Additionally, mangroves are known to play a vital role in fish population ecology in terms of providing breeding grounds and also acting as a nursery for juvenile fish. Thus, due to the migratory patterns of the fish species, it can be postulated that mangroves contribute to the wellbeing of global fish populations and the fisheries sector. However, some of the functions of the mangroves and their benefits are localised as the community in close proximity to them are the sole and immediate beneficiary. For instance, products such as timber, fuel wood and subsistence fishing are generally for local consumption. For the Limpopo mangroves, benefits such as medicinal material obtained from the mangroves are restricted to the communities found in close proximity to them, namely Zongoene, Voz de Frelimo and Chilaulene. Moreover, the protective functions of the mangroves are also restricted to the immediate communities, as are many economic activities.

Temporally, the benefits of the mangroves vary markedly. Some benefits are highly dynamic. For instance, a member of the community noted that fish can be easily caught during the low tides as compared to during the high tides. Similarly, the protective function of mangroves against salty water intrusion and in dissipating wave energy is relatively more efficient during high tides and during flood and storm periods than during low tides. Additionally, products such as timber and fuel wood are harvested from mature vegetation. Thus, temporally, the benefits are realised with time. Table 3 depicts a categorisation of the different functions and services provided both spatially and temporally.

Table 3: Categorization of mangroves products, functions and services - spatially and temporally

Functions and services		Temporal		Spatial	
	Global	Regional	Local	Yearly	Seasonal
Carbon sink and climate change mitigation	X	X	X	X	
Microclimate properties			X	X	
Groundwater functions			X		
Storm control			X		X
Prevention of coastal erosion			X	X	X
Control of salty water intrusion			X		X
Timber and fuel wood			X	X	X
Tourism potential		X	X	X	X
Research and scientific	X	X	X	X	X
Apiculture			X		X
Aquaculture			X	X	X
Sedimentation control and protection of Sea Grass and Coral Reef			X	X	X
Commercial fish	X	X	X	X	X

2.6 Conclusions

Mangroves comprise trees and shrubs that grow in salty and brackish tropical environments. They are highly productive ecosystems with a primary productivity of approximately 2 grams day^{-1} m^{-2}. They are thus a major carbon sink. Mangroves are also multifunctional providing both ecological and economic functions and services that are highly valuable. The Limpopo mangroves are found in the proximity of the Limpopo River estuary and are characterized by five types of plant species:- *Avicennia marina* (Grey Mangrove or White Mangrove), *Rhizophora mucronata* (Loop-root Mangrove, Red Mangrove or Asiatic Mangrove) *Bruguiera gymnorrhiza* (Black Mangrove), *ceriops tagal* (Indian Mangrove) and *Xylocarpus granatus* (Cannonball Mangrove or Cider Mangrove). The ecosystem has recorded about 120 fish species and various types of crustaceans such as burrowing crabs, hermit crabs, fiddler crabs, shrimps and prawns. The mangrove species (flora and fauna) provide a diverse array of ecological functions and services. Ultimately, the ecological services provided by mangroves such as control of tidal waves, regulation of sedimentation loads in the marine ecosystem are attributed to the ecosystem flora and fauna. Evidently, these ecological services protect the shoreline against erosion, and also protect Sea grass and coral reefs. In addition, mangroves as a carbon sink provide the global service of climate change mitigation. The services offered by mangroves are of high economic value. However, there is a major information gap concerning the economic value of mangroves. This lack of information is one of the underlying factors behind the deforestation and degradation of the mangrove ecosystem. In order to close the information gap, the next section of the report attempts to put a monetary value on the products, services and functions.

3. Economic Valuation of Mangroves Ecosystem in Limpopo estuary

3.1 Introduction

The section of the report entails economic valuation of mangroves ecosystem in the Limpopo estuary. Ecosystem valuation involves putting a dollar value on mangroves products, functions and services. This is done under the auspices of the Total Economic Value (TEV) concept. Valuation exercises form an important basis for optimal management of ecosystems such as mangroves through integration of costs and benefits in economic decision making. The environmental benefits of ecosystem valuation include:

- It creates a platform for ecosystem benefits maximization and costs minimization hence optimization.
- It gives a strong supportive argument for ecosystem conservation.
- Values of ecosystems can be integrated into national accounts to demonstrate the contribution of ecosystems to the national wealth.
- It creates a platform for development of Payment for Ecosystem Services (PES) programs.

Consequently, the main objective of ecosystem valuation is to demonstrate the economic value and importance of natural resources in contributing to the country's wealth as measured by GDP. Ultimately, it is envisaged that valuation will advocate for sustainable use of mangrove ecosystems and also provide strong supportive evidence for mangrove reforestation programs.

3.2 Approaches and methods

Mangrove ecosystems are multi-functional, providing a wide range of products, functions and services that are beneficial to both the economy and environment. The appropriate approach to ecosystem valuation is by taking into account all the uses and non-use benefits associated with the mangroves. This approach is based on the Total Economic Value (TEV) concept. TEV is simply defined as a summation of the uses and non-use values associated with an ecosystems' functions and services (figure 2).

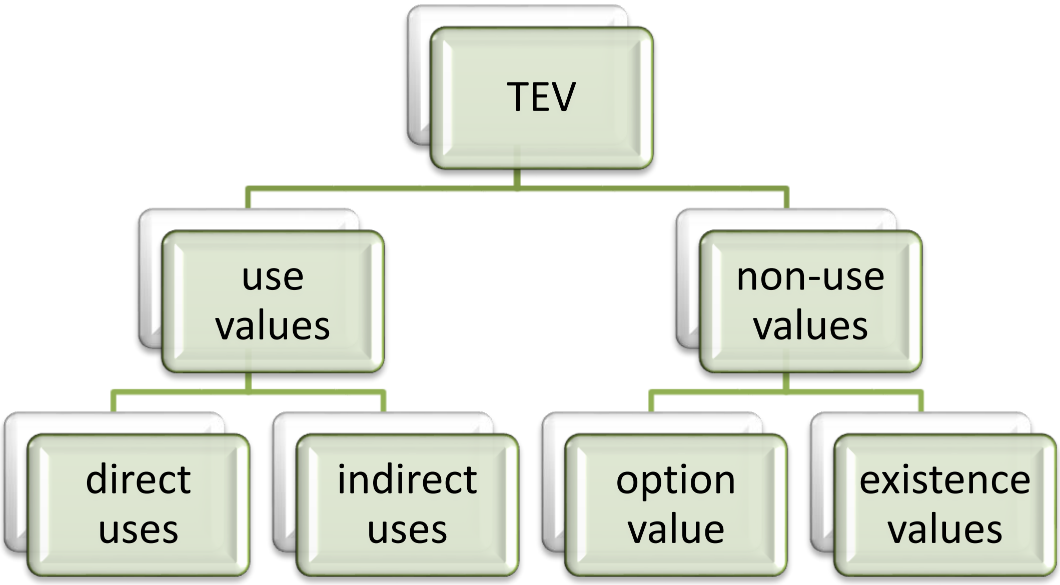


Figure 2: TEV Framework for Mangrove Valuation

User values are the benefits derived from direct and indirect consumption of mangroves ecosystems goods and services. On the other hand, non-use values are those values that have no association with utilization of mangroves products and services; they include option and existence values.

Option value is the value associated with the premium an individual is willing to pay (hereinafter WTP) for ecosystem conservation to keep future resource utilization open. It is based on the notion that even though a resource is presently not used, it has potential to be used in the future. Hence an individual is effectively paying an insurance fee to keep options of future use open.

Existence value is associated with the value that people place on simply knowing something exists, even if they will never see it or use it. It is the WTP for the mere continuation of the survival of a species or ecosystem. Thus, the knowledge that an ecosystem exists gives an individual some form of satisfaction which can be equated to their WTP.

Figure 3 below depicts a schematic approach that was adopted for valuation of the mangrove ecosystem.

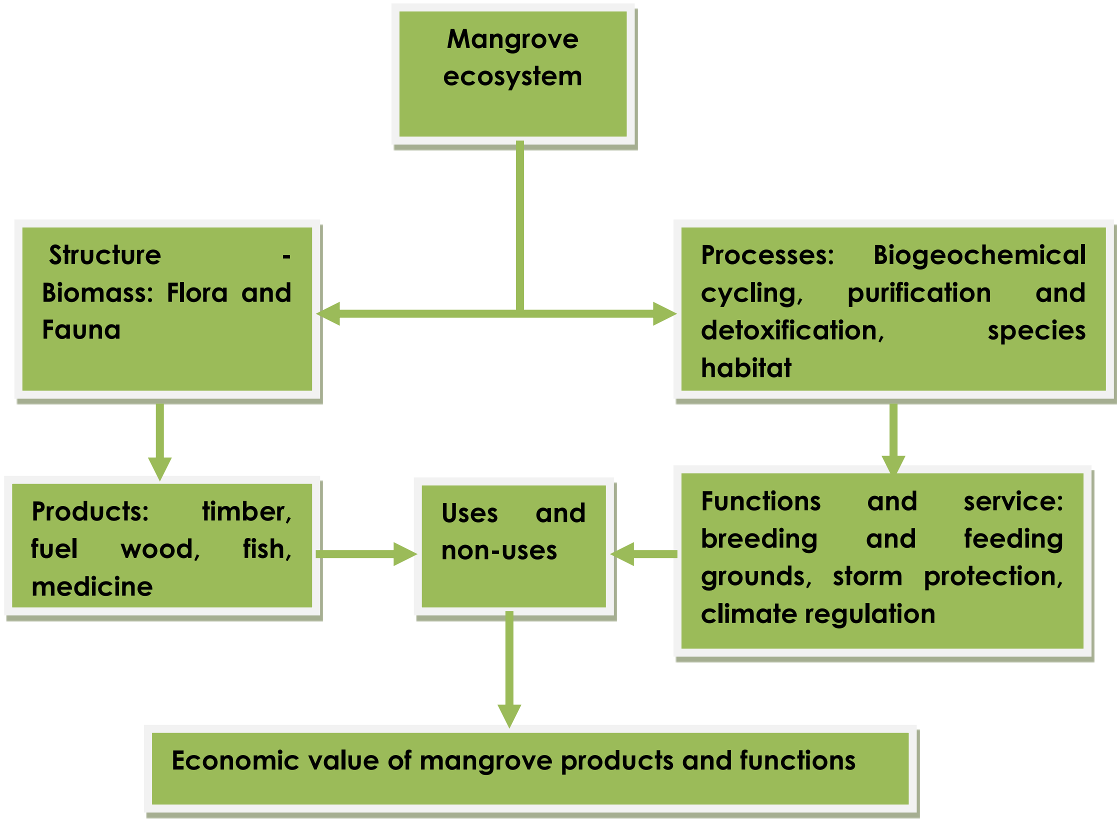


Figure 3: Mangroves ecosystem valuation approach

As highlighted, mangroves offer a diversity of products, functions and services that are of benefit to the economy and households. These diverse products, functions and services are used differently (either directly, indirectly or have the potential to be used). Logically, each product, function or service would require a different valuation approach and technique to infer to its economic value. Below is a list and description of the methods that were employed to value mangrove products and functions.

- Production Functions Methods: these are indirect valuation methods that infer to the value of ecosystem functions and services through their contribution to production of marketed goods and services. In many instances, ecosystems play an essential role in the production of marketed goods and services. Therefore, the value of ecosystems is inferred through its contribution to production functions. This technique relies on establishing a change in environmental parameters and determining the response of the production process. Based on the established relationship, the impact of ecosystems is quantified and valued.
- Market values: some ecosystem products such as timber are marketed. Therefore the prices of the marketed products will be used to inform the value of mangroves. This method relies on the market prices and the annual harvest. However, there are some market distortions due to externalities. For instance, the market price for timber

excludes lost services such as carbon sequestration and soil erosion prevention. Even so, market values will be used to infer the value of ecosystem services.

- Surrogate market price approach: this method is based on the rational that though some mangrove products or functions are not necessarily sold in a market, they have close substitutes which are marketed. Therefore, the price of a close substitute can be used to elicit the value of a non-marketed mangrove product.
- Replacement and avoided costs: ecosystems provide services that reduce and prevent economic costs such as reducing the impacts of extreme events (floods, hurricanes, storms). Therefore, the costs that could have been incurred had the ecosystem been degraded, can be used to estimate the value of mangroves in terms of offering protection services. In addition, the replacement cost method attempts to estimate the cost of restoring after the damage. These methods will be used to calculate the value of mangroves as provider of services.
- CVM: this is a valuation technique that is used to value both use and non-use values of ecosystems. It is a direct and hypothetical valuation technique also referred to as State Preference Method (hereinafter SPM). It is SPM because unlike other methods where values are revealed through an association with a marketed good, CVM directly asks individuals their WTP for a function or product. This is achieved through the use of questionnaires. In this assignment this method will be used to estimate the option and existence value.

Table 4 below summaries proposed methods to be employed for mangrove products and services.

Table 4: Proposed methods for biodiversity valuation

Ecosystem functions and services	Method/Approach	Advantage	Limitation
Timber	Market price for timber	Availability of data	Market price do not factor in externalities
Fuelwood and charcoal	Market price and surrogate market	Availability of data for price Consumption quantities	Market prices do not factor in externalities
Medicinal products	Avoided health care cost Market price	Availability of data on cost of health care and market price/charges	Quantity of medicinal plants harvested lacking
Carbon sequestration	Market price of carbon	Data is available	The price of carbon might not be the true cost of the impacts of carbon dioxide
Storm prevention/control	Mitigation costs	The method is simple and data readily available	Cannot be employed where there are no mitigation measures and properties
Tourism	Travel costs/market prices	Application of the method is easy	Based on the premises that tourism is a normal good which could be wrong
Apiculture	Production function and market prices	Contribution of mangroves to honey production and production quantity and price available	Will undervalue the service if honey production is not optimal
Food (fish, berries, nuts etc.)	Market price	Data is ready available	Suffers from market distortions
Option value	CVM	Easy to apply	Hypothetical and strategic bias
Existence value	CVM	Easy to apply	Hypothetical and strategic bias

3.3 Mangrove products, functions, services and their estimated values

Mangrove ecosystems in the Limpopo Estuary play an important socio-economic role to community welfare and the country at large. Primarily, they contribute to food security and income generation through sales of products such as fish, timber and charcoal. Additionally, mangrove ecosystems contribute to job security and employment as members of the community are employed in mangrove related economic activities. Consequently, through creation of employment, mangroves have a positive feedback on household income generation. Overall, mangroves contribute to poverty alleviation and generally improved quality of life for the community in the proximity of the mangrove ecosystems.

In the main, estimating the economic value of mangroves products, functions and services requires an exhaustive list of all the mangroves products and services to be compiled. Consequently, values need to be estimated for individual products, functions and services. It is also logical to separate the direct use values from the indirect and non-use values. The rational for separation is the fact that the complexity and uncertainty of valuation increases from direct, to indirect and non-use values.

3.1.1 Direct uses of mangroves

Mangrove ecosystems have a diversity of direct uses in the Limpopo estuary. Salem and Mercer (2000: 361) define direct uses as "consumptive and non-consumptive uses that entail direct physical interaction with the mangroves and their services". Evidently, as these direct uses are beneficial to the economic activities and economic agents it inevitably implies that they have economic values. In contrast to other uses, direct uses are easier and straightforward to value. A mangrove utilization survey in the three settlements of Zongoene Sede, Voz de Frelimo and Chilaulene revealed that the main products harvested are traditional medicine, fuel wood, timber, construction material, fish and crustaceans. Figure 4 depicts the ranking of the products in terms of their importance. Clearly, fish, crustaceans and fuel wood are the most important in the three villages.

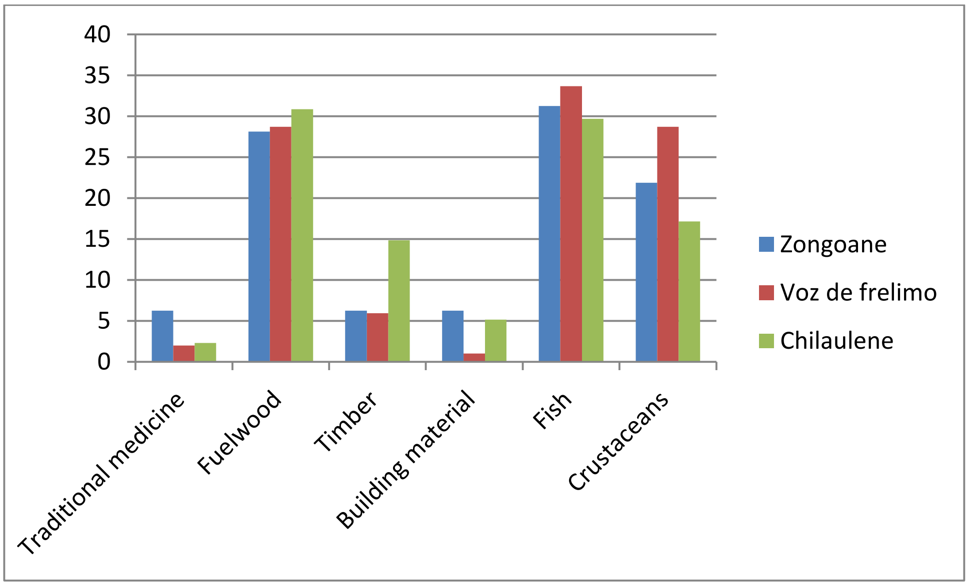


Figure 4: Ranking of mangrove products in terms of importance

3.1.1.1 Fuel wood

Fuel wood is one of the primary sources of energy for the rural population in Mozambique. For communities residing in the coastal areas such as Limpopo Estuary, mangroves are the main source of fuel wood. Though not sustainable, this direct use value of mangroves is one of the most substantial as it is widely used by the majority of the rural community residing in close proximity to the mangroves.

Two valuation methods that can be used to estimate the value of mangroves as a source of energy (fuel wood) are market price and market surrogate prices. These are discussed below.

Market price of fuel wood: households collect fuel wood for either home consumption or sale. There are those members of the community who harvest fuel wood for solely commercial purposes. Thus, fuel wood has a market and automatically a price. It is therefore presumed that the price is determined by the market forces of demand and supply due to perfect competition. Therefore the price can be used to estimate the economic value of mangroves as source of fuel wood.

Market surrogate price: this method estimates the value of fuel wood based on the price of a close substitute. A substitute of fuel wood is electricity and LPG both of which have a market and therefore a price.

Determining the economic value based on the methods require the following information:

- Annual total fuel wood harvested
- Market prices
- Production costs (labor, transportation, packaging)

Assessment reveals that mangroves constitute approximately 25% of household energy demand. Furthermore, survey revealed that on a weekly basis, this accounts for 4 kg of fuel wood per household. Based on these findings, table 5 depicts the derived economic value of mangroves as source of fuel wood.

Table 5: Value of fuel wood from mangroves

Settlement	Proportion of household harvesting fuel wood (%)	weekly harvest of in Kg	number of household	consumption per village (kg)	Average Price per kg	Value (MZN)
Zongoene	32	40	2055	2630.4	20	52,608.00
Voz de Frelimo	31	40	3363	4170.12	35	145,954.20
Chilaulene	33	40	3809	5027.88	32	160,892.16
					Annual value	359,454.36

3.1.1.2 Charcoal

This is another source of energy that originates from mangroves. Studies have suggested that charcoal from mangroves has the highest calorific values. The same valuation approaches that were used for fuel wood can be used to solicit the economic value of mangroves as a source of energy for the communities. Even though currently, members of the communities are not producing charcoal from the mangroves there was prolific production of charcoal after the year 2000 floods.

3.1.1.3 Timber

Similarly, mangroves are a source of timber which is used for construction purposes. Timber from the mangroves is used for construction of houses and livestock kraals. As in the case of fuel wood, timber poles have a market and thus a price. Therefore, the price can be used to inform the economic value of mangroves as a source of timber. The value is a function of the quantity harvested and the net market price. Table 6 below depicts the economic value of timber obtained from the mangroves.

Table 6: Value of timber from Mangroves

Timber	Proportion of household harvesting (%)	Annual harvest (kg)	Number of households	Consumption (kg)	Average Price (MZN/kg	Value (MZN)
Zongoene	9	150	2055	27199	120	3,263,823.53
Voz de Frelimo	11	160	3363	59787	100	5,978,666.67
Chilaulene	23	200	3809	175214	200	35,042,800.00
					value	44,285,290.20

3.1.1.4 Livestock browsing

Mangroves are an important source of grazing for livestock such as camels, goats and other browsers. Additionally, mangroves play a critical role in reducing the community's vulnerability to drought episodes as livestock browse the lush vegetation. Thus, the mangroves have an economic value as a source of fodder for livestock. Estimating this economic value is generally based on the surrogate market price approach as fodder provided by the mangroves has a marketed alternative or substitute. Similarly, the avoided cost of supplementary feeding by farmers can also be used to solicit the economic value of mangroves as a source of fodder. However, the mangrove resource utilization survey revealed that Limpopo livestock do not browse or graze within the mangroves.

3.1.1.5 Traditional medicine

Mangrove forests have traditionally been used as a source of medicine by the local communities. Some of the aliments that have claims of being cured through medicine extracted from mangrove trees such as *Avicennia Africana* include cancer, thrush, gangrenous wounds, lice, mange, ring worms, skin parasites, tumors and ulcers. From the above list it is clear that mangroves play a crucial role as source of medicine particularly to those households who could not access hospital due to fees and the distance (travel costs).

There are various approaches to solicit the economic value of mangroves as a source of medicine. However, the most simple and reliable ones are the surrogate market price approach and the market prices of traditional medicine. Based on the highlighted methods, the value of medicinal plants is estimated as the amount of money saved from purchasing modern medicine. Conversely, it is the amount of money an individual would have incurred had they gone to the general health practitioner for medical attention. Table 7 below depicts the variables determining the value of mangroves and the estimated economic value of mangroves.

Table 7: Value of Traditional medicine from mangroves

Settlement	Proportion of household harvesting (%)	Quantity harvested in a year (kg)	Number of households	Total harvest (kg)	Average Price for treatment	Economic Value
Zongoene	3	5	2055	302	600	181,324.00
Voz de Frelimo	1	5	3363	208	600	124,556.00
Chilaulene	4	5	3809	762	600	457,080.00
					Total	762,959.08

3.1.1.6 Pharmaceutical products

Similarly to traditional medicines, mangroves have a great potential as a source of pharmaceutical products and genetic resources. Currently, there are no pharmaceutical companies that are engaged in production of modern medicine in the Limpopo Estuary mangroves. Therefore, the economic value of the mangroves as a pool for pharmaceutical products cannot be inferred.

3.1.1.7 Apiculture

Apiculture is the production of honey and it is one of the functions of mangrove ecosystems due to the prolific presence of flowering plants particularly *Apis mellifera*. Compared to other direct uses of mangroves, this use is one of the most sustainable as it does not have significant environmental impacts.

Estimating the economic value of mangroves as a source of honey production is based on production of honey and the market price of honey. Table 8 depicts the estimated value of mangroves as contributing to honey production by providing nectar. Consultation with stakeholders indicated that honey production is not optimal mainly because honey from mangroves has salty taste as compared to other forests. Therefore, consumers' preference is lower for mangrove honey.

Table 8: Honey production from mangroves

Honey production (kg/year)	Market price of Honey (USD/kg)	Economic value of honey (MZN/year)
200	250	50,000.00

3.1.1.8 Fish and shellfish resources

Fish resources are one of the most important products that have a direct relationship with mangrove ecosystems. Mangroves provide a habitat for various fish species which are harvested by the local communities. A survey of fishermen revealed that mangroves have a high productivity as far as fish production is concerned. They revealed that one (1) hour of fishing in the proximity of mangroves yields approximately 4 kg of fish while the same hours of fishing far from the mangroves yields between 0.5 to 1 kg.

Estimating the value of mangroves as a source of fish is based on fish harvested, type of species and the market price of fish. Table 9 and 10 depicts the economic value of mangroves as habitat for fishery resources.

Table 9: Economic value of mangrove as habitat for fish

Settlement	Proportion of household harvesting (%)	Daily catch (kg)	Number of household	Catch per day (kg)	Average price (MZN)	Economic value (MZN)
Zongoene	24	4	2055	1934	76	36,748,235.29
Voz de Frelimo	37	4	3363	4982	71	88,434,444.44
Chilaulene	22	4	3809	3352	70	58,658,600.00
					Total	183,841,279.74

Table 10: Value of crustaceans harvested from the mangroves

Settlements	Proportion of household harvesting (%)	Daily catch (kg)	Number of household	Catch per day (kg)	Average price (MZN)	Economic value (MZN)
Zongoene	24	10	2055	4835	69	83,408,823.53
Voz de Frelimo	17	4	3363	2325	46	26,737,925.93
Chilaulene	5	8	3809	1523	47	17,902,300.00
					Total	128,049,049.46

3.1.1.9 Aquaculture

Another direct use of the mangroves is fish farming. Revenue generated from the fish farms contribute significantly to the household income. Estimating the economic benefit of mangroves as a source for fish farms is normally based on the market price approach. However, although there are aquacultures constructed by CDS, they are currently not functional as they have been flooded. If optimized, the economic value of aquacultures could be highly significant.

3.3.2 Total Direct Use Value

Total direct use value is a summation of all the economic values derived from consumption or direct utilization of mangrove products. Based on the market price approach and surrogate market price approach, total direct use value for the mangroves is estimated at MZN 357 million per year.

3.3.3 Indirect uses of mangroves and their values

Correspondingly, mangrove functions are invariably used and benefit economic agents through their indirect contribution to the production of economic goods. These benefits are similar to direct benefits and have economic values. However, estimating the economic value realized from indirect use values is relatively complex. In the next section, an attempt is made to estimate the value associated with indirect use of mangrove functions and services.

3.3.3.1 Offshore fishery

Mangroves play a critical role in supporting commercial fishing by providing nursery, breeding and hatching environments to offshore fisheries (Blaber, 2007; Salem and Mercer, 2012). Thus, estimating the economic value of mangroves as contributing to commercial offshore fishing involves determining the dependency rate of offshore fisheries to mangroves. Based on the dependence rate, the value of mangroves can be estimated as a proportion of total annual value of commercial fishing. Globally, various studies have been undertaken to estimate the dependency rate of offshore fisheries to mangroves (Ronnback, 2001; Spurgeon, 2002). As per the findings of various analyses, it is estimated that the dependency rate of offshore fishing to mangroves ranges between 30 to 80% of fish catches and 100% for shrimps. Therefore, a proportion of total value of fish is attributable to the mangroves. This is based on the reasoning that without mangroves, fish productivity would decline by an amount corresponding to the dependency ratio. It is estimated that commercial offshore commercial fishing constitutes approximately 15% of the total value of the fishery sector in Mozambique (USAID, 2010). Based on the estimated value of USD 59 million, table 11 depicts the value mangroves have by contributing to offshore fishing.

Table 11: Economic value of mangroves as contributing to offshore fishing

Total value of commercial offshore fish (MZN)	Dependency rate of offshore fishing (%)	Percentage of Limpopo mangroves to national (%)	Value of Limpopo mangroves (MZN)
59 000 000.00	50	1%	29,500,000.00

3.3.3.2 Carbon sequestration

Mangroves are an important carbon sink and source of carbon sequestration. It has been suggested that mangroves are among the most carbon-rich ecosystems on the planet with estimates that they have double the living biomass as compared to tropical rainforests (Sitoe et al, 2014). Consequently, mangrove ecosystems are an important ecosystem for mitigating climate change and associated impacts.

Three ways of estimating the economic value of mangrove ecosystems as a source of carbon sink and sequestration include:

- market price approach
- damage cost avoided
- replacement costs

However, due to lack of information on costs associated with emissions per ton of GHGs, the market price approach is preferred. Application of the market price approach entails the following:

- quantifying the carbon stored per hectare
- annual carbon sequestrated per hectare
- total area coverage of mangroves
- market price of carbon

Based on recent mangrove coverage mapping, table 12 depicts mangrove status and their area coverage.

Table 12: Mangroves status and area coverage in Limpopo

Mangrove status	Area (ha)
Degraded mangrove	133.34
Dispersed mangrove	269.67
Dense mangrove	62.67
Total	465.68

Source: Silva et al (2014)

Various studies have been conducted on mangrove carbon stores both regionally and internationally (Sitoe et al, 2014; Fatoyinbo et al, 2008). The latter authors estimated the aboveground tree biomass for Gaza mangrove to be approximately 207 Mg ha^{-1}. Additionally, due to the extensiveness of the mangrove roots systems, studies estimate belowground biomass from the mangroves to account for 70-85 percent of total biomass. Therefore the belowground biomass of mangroves is estimated to be 360 mg ha^{-1}.

Basing on the findings that the amount of Carbon is approximately 50% of the biomass (Lieth and Whitaker, 1975; Piao et al, 2005) and the following assumption:

- degraded mangroves account for 20 percent of biomass
- dispersed mangroves account for 50 percent of biomass
- dense mangroves account for 100 percent biomass

Estimating carbon sequestration was based on the findings that mangrove primary productivity is 2.5 g carbon m^{-2} day^{-1} translating into 9.125 mt ha^{-1} $year^{-1}$. It is assumed that this figure accounts for both above and belowground biomass. This was estimated for degraded and dispersed mangrove areas only.

Table 13 shows the estimated carbon stored in the Limpopo System Mangroves. The total estimated carbon stored is approximately 0.5 percent of the country's total carbon stored in mangrove ecosystems. Thus, given the fact that Limpopo mangroves account for less than 1 percent of the mangrove ecosystem in Mozambique the derived figure was assessed to be within acceptable limits.

Table 13: Estimated carbon store and sequestrated in the mangroves

Dense mangrove				
Category	Total biomass	Biomass growth	Carbon stock (Mt)	Carbon sequestrated (mt)
Above ground biomass	12972.69	0	6486.35	0
Below ground biomass	22561.2	0	11280.6	0
Dispersed mangrove				
Above ground Biomass	27910.84	984.2	13955.42	492.1
Belowground Biomass	48540.6	3937	24270.3	1969.5
Degraded mangrove				
Biomass aboveground Biomass	5506.2	486.6	2753.1	243.3
Belowground biomass	9576	1942	4788	971
		Total carbon	63533.72	3675.9

Table 14: Economic value of mangroves as source of carbon store

Total carbon (Mt)	Price (MZN/Mt)	Value of carbon (MZN)
63533.72	600	38,120,232.00

3.3.3.3 Flood and flow control/shoreline protection function

Mangrove ecosystems dissipate wave energy and thereby protect the shoreline and prevent coastal erosion. This is achieved through its complex root systems. This function is of particular importance as it protects the crucial terrestrial habitats from becoming severely eroded and damaged. Economically, this ecological function is important for agricultural production as it protects agricultural lands from the intrusion of salty sea water. Evidently, without the mangrove ecosystem agricultural productivity would be significantly affected. Additionally, mangroves reduce the impacts associated with extreme events such as hurricanes, cyclones, tsunamis and storm surges.

Estimating the value of mangroves as providing a defensive system against wave energy can be done through the damage costs avoided and replacement costs approaches. Damage costs avoided is based on the notion of estimating the damage costs that could have been incurred had the system being breached or absent. A logical approach to applying the damage costs avoided is by deriving the damage cost curve based on degraded mangroves or coastlines where there are no mangroves and extrapolating the findings to the site of interest.

On the one hand, replacement costs method is a valuation technique that is based on estimating the costs of repairing the damage after the incident. It is effectively synonymous with the construction of dykes to prevent the storm damage.

Survey results revealed that all of the respondents indicated that without mangroves, there would be no agriculture in the Limpopo estuary (Zongoene settlement). They highlighted that there is a strong correlation between agricultural fields and mangroves. Therefore, based on this relationship it can be postulated that the value of agriculture can be assumed to be equal to the protective function of mangroves. However, due to the lack of data on agricultural yields, the protective function of mangroves to agriculture could not be estimated.

3.3.3.4 Storm buffering/ sediment retention

One of crucial roles played by the mangroves is to regulate sediment movement and thus the rate of sediment deposition (Salem and Mercer, 2012; Spurgeon, 2002; Ronnback, 2001). Significantly, sedimentation regulation has two dimensions. Firstly, mangroves aid in filtering terrestrial sand and preventing it from being blown along the shore, so reducing the rate of sand deposition into the fringing reefs. Additionally, during flash floods, which are frequent in the Limpopo estuary, mangroves through their advanced and complex root systems significantly reduce the speed of sediment laden flood water. This process culminates in the settling of sediments within the mangrove environment. Consequently, these processes protect coral reefs from being buried by excessive sedimentation (Spurgeon, 2002). This ecological function of mangroves is of high economic value given the economic significance of coral reefs. In the main, it implies that mangroves protect the following functions of coral reefs:-

- Acting as a barrier by preventing sediments from corroding the shoreline
- Carbon sequestration
- Construction material
- Medicinal purposes and manufacturing of jewelry
- Habitat for fish used for aquariums

Estimating the economic value of mangroves in providing the function of storm buffering and sedimentation control can be achieved through the damage avoided costs and replacement costs approaches. However, due to the lack of data on coral reefs coverage, fish harvests from coral reefs and the quantity of coral reefs harvested, it was not possible to estimate the value of mangroves. Nevertheless, as coral reefs also contribute to fish production and commercial fishing, this function has been estimated under commercial offshore fishing.

3.3.3.5 Total indirect use value

Total indirect use value is a summation of all the economic values derived from indirect utilization of the mangroves (protective function, offshore fishing, carbon sink etc.). It is estimated at MZN 67 million per year.

3.3.3.6 Total use value

Total use value which constitutes direct and indirect uses of the mangroves is estimated at approximately MZN 424 million. Uses that contribute significantly to this total economic value of mangroves are fish, fuel wood and crustaceans. This finding confirms the survey results where communities ranked fish, crustaceans and fuel wood as the mangrove products that contribute significantly to their livelihoods.

3.3.4. Non-use values

Conversely, non-uses as the name implies are non-economic activities that are not associated with the consumption of ecosystem products. They are synonymous with the conservation of ecosystems. Though individuals are not using the ecosystem products or functions, they will have a positive WTP or WTA for their existence or appreciation. Thus, in the next section, types of non-uses are discussed together with their corresponding WTP value. It is postulated that individuals will be WTP for not using the ecosystems for the following reasons:-

- To use the resource in future either by themselves or future generations;
- The knowledge that the resources or mangrove exists gives them satisfaction which is a health benefit

3.3.4.1 Existence value and option value

Option and existence value fall under non-uses of mangroves. Estimating non-use values was achieved by using the CVM method which is a SPM. It is a SPM as individuals state their WTP based on the developed questionnaire. Consequently, a questionnaire was developed and administered to members of the communities for the three settlements.

For the three settlements, a high proportion of the respondents indicated that they would be willing to participate in the mangrove reforestation project (Figure 5).

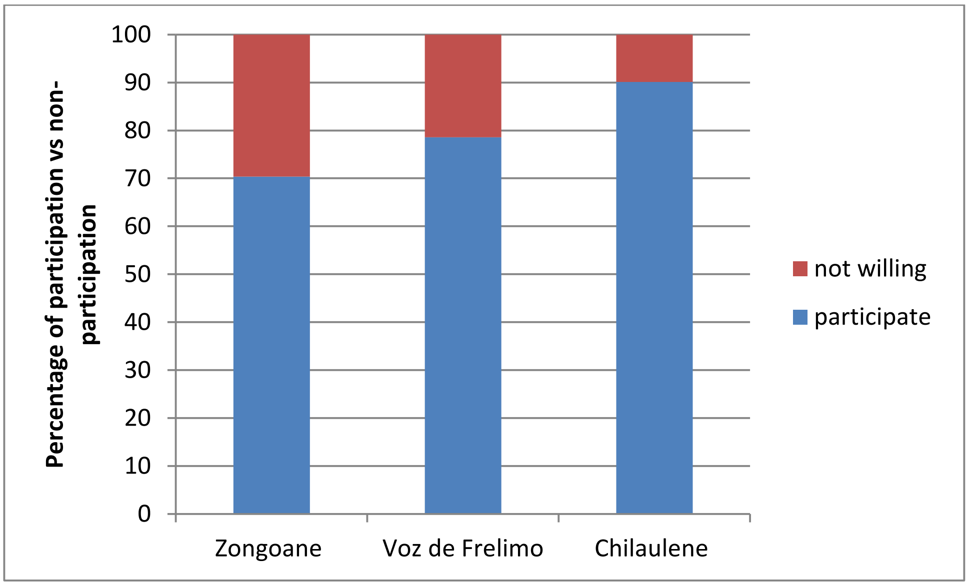


Figure 5: Percentage of participation vs non-participation in Mangrove reforestation project

Respondents were given two (2) options as payment; being payment in cash and labor. Figure 6 depicts that a high proportion of the respondents indicated that they would be willing to pay through labor while only 14 percent revealed that they would be WTP for the mangrove reforestation. This finding is logical and consistent with the high level of unemployment in rural Mozambique.

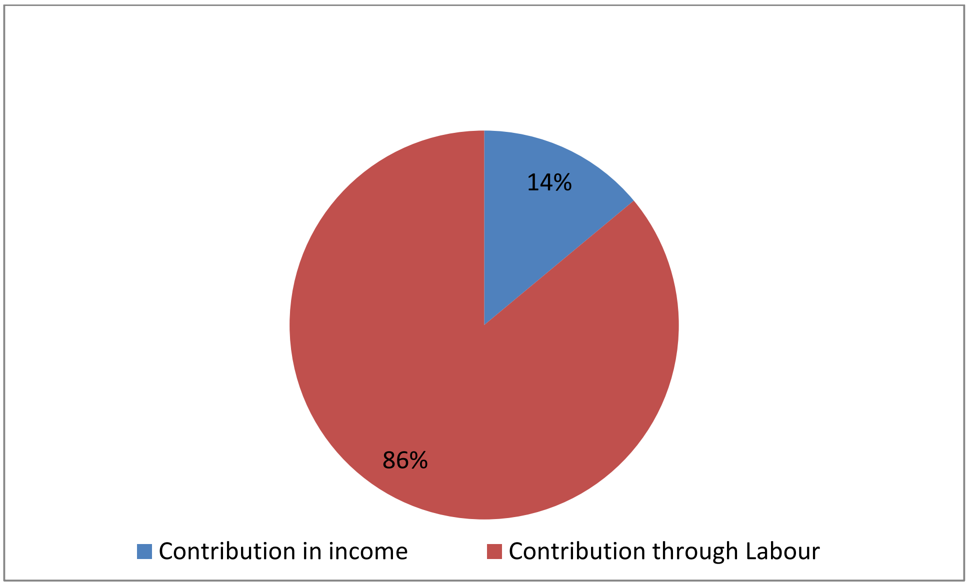


Figure 6: Method of participation in Mangrove reforestation project

For those respondents who indicated that they would be willing to contribute in cash, their mean WTP is MZN 70 per month for the duration of the project. Figure 7 depicts WTP distribution which is slightly normally distributed around the mean WTP (MZN 70/month).

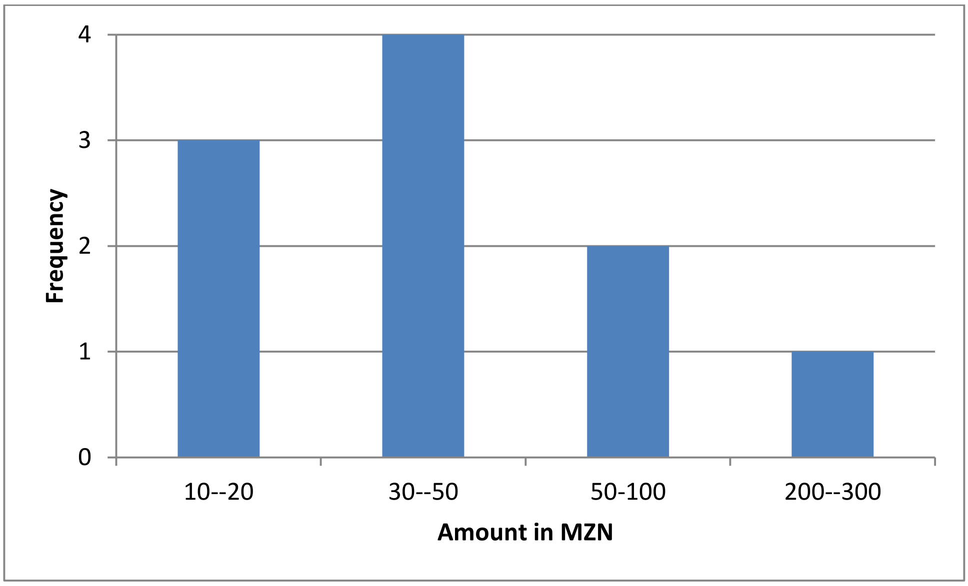


Figure 7: Revealed WTP for mangrove reforestation project

As indicated majority of households indicated that they prefer contributing in labor to the mangrove reforestation program. On average the mean number of days that individuals indicated as a contribution was 10 days in a month for the entirety of the project period. Figure 8 depicts the revealed number of days in a month that individuals prefer to participate in the reforestation project. This is negatively skewed around the mean. Based on the informal sector salary of MZN 2000 per month for the agriculture and livestock sector, the opportunity cost of labor which is defined as the WTP for mangrove reforestation is equivalent to MZN650 per month. Thus for the individual who prefers to contribute through labor, their WTP is higher than those WTP by cash. Thus, the revealed WTP ranges from MZN70 to MZN 650 per month for the duration of the project.

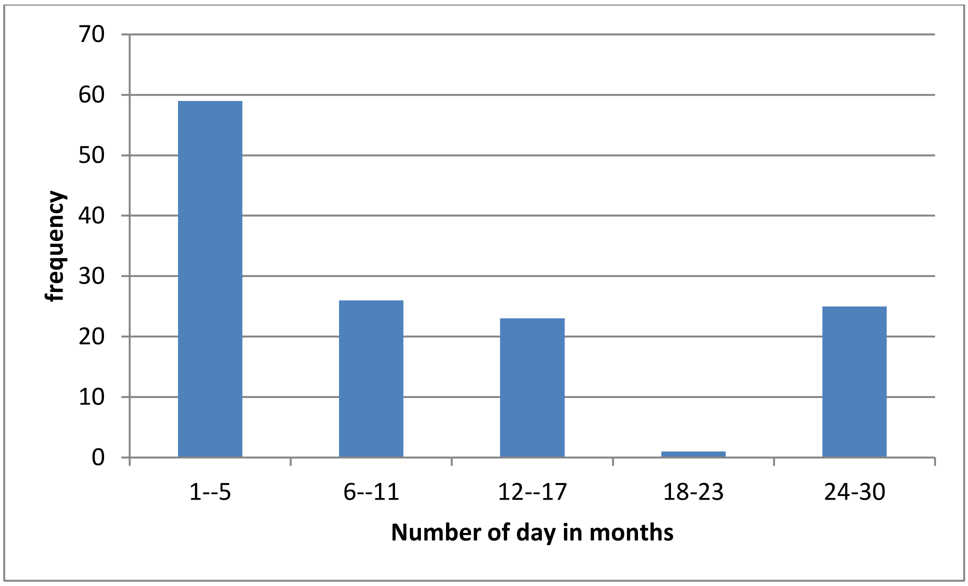


Figure 8: Distribution of contribution through labor for reforestation

Assuming that the survey does not suffer from both strategic and hypothetical bias, and that for each household, 2 members would contribute to the mangroves reforestation. Table 15 depicts the option and existence values for the mangroves according to members of the three communities.

Table 15: Total WTP for mangrove project

Number of household	Number WTP in cash	Number WTP in labor	Average WTP (MZN)	Average WAGE (MZN)	Economic value (MZN)
3809	373.282	2293.018	70	650	18,199,097

3.4 Conclusions

Mangroves are highly valuable ecosystems as evident from their estimated total economic value of MZN 424 million. Thus, the total use value for the Limpopo estuary is estimated at approximately MZN 0.9 million ha^{-1} $year^{-1}$. This translates in to USD 28,125 ha^{-1} $year^{-1}$. Though the derived value is relatively high compared to the range given by the Spalding et al, (2010), it is important to note that other functions such as protective functions that benefit the agricultural sector have been left out. It is also crucial to realize that the direct use value is conspicuously higher than the indirect use value. This finding raises the fundamental issue of sustainable utilization of the mangroves. Moreover it follows that mangroves in the Limpopo estuary are directly and intensively utilized, while the indirect uses are in fact limited. It is therefore important that more emphasis is placed on indirect utilization of mangroves to encourage their sustainable utilization. Additionally, members of the community revealed a significantly high WTP for the mangroves reforestation project. Thus, the revealed options and existence values indicate that members of the community realize the benefits of the mangroves. Lastly, the findings of this assignment directly points to the fact that there is a need for the design and implementation of PES mechanisms for the generation of revenue for mangroves conservation.

4. An assessment of sustainability of mangrove reforestation project

4.1 Introduction

This section discusses findings of the evaluation of mangrove reforestation sustainability Project which has been initiated by CDS-ZS in collaboration with RESILIM. The project is undertaken on degraded mangroves in the Limpopo estuary due to the aftermath of the year 2000 floods. The floods resulted in inundation of mangrove forests for over 2 weeks culminating in all the plants dying. CDS-ZS initiated the project in 2010 and has already covered over 30 hectares. The sustainability of the project is evaluated on the following aspects:

- Economic sustainability: this aspect of sustainability assesses the financial returns of the project from a social and environmental perspective. Therefore, instead of employing financial Cost benefits analysis (CBA), social CBA is used. Additionally, the financing mechanism for the project is also assessed in order to determine the dependability of the project on external funding.
- Social sustainability: mangrove ecosystems are under tremendous pressure from anthropogenic activities mainly demand for fuel wood, deforestation for cultivation and construction material. Ultimately, it is pertinent that a sustainability assessment takes into account the pressure on mangrove forest to determine whether newly established mangroves forests will be exposed to similar pressures. Moreover, institutional and community capacity to implement the project is also assessed. This has been done in order to determine the extent to which the project is dependent on external skills and manpower for implementation. Therefore, willingness of the community to participate in the project has been assessed.
- Ecological sustainability: equally important is ecological sustainability. Ecological sustainability encompasses evaluation of the extent to which the ecological setting has altered to permit revegetation/establishment of the planted mangroves seedlings. This will involve land use changes, soils properties and species composition within the deforested areas. It is important to point out that particular emphasis has been put on soils, species composition and land uses as climatic conditions are generally long term and do not change abruptly to affect the establishment of the seedlings.

4.2 Methods and approaches

Achieving the three components of sustainable Mangrove reforestation required a diversity of methods including economic, social and ecological approaches. The following are some of the methods employed in the endeavor to achieve the intended results:

- CBA: this is an appraisal technique that determines the viability of the project by estimating the Net Present Value (hereinafter NPV). It is a measure of project's viability by comparing the stream of costs and benefits over time. The costs and benefits are identified, quantified, discounted to estimate NPV. Consequently, the project lifespan is estimated to enable deriving costs and benefits over time. There are two types of projects- private and social. As this project is classified as a social project, social CBA will be used where the benefits realized by the community from the project will be assumed to be a stream of revenue flows. Therefore, economic values derived from valuation components will be used as benefits. On the other hand, the costs incurred in foresting 30 hectares will be used to project future costs for the project.
- Institutional and financial scorecard: a scorecard is a tool that is used to assess the performance of an entity over a set of criteria and targets. It is made up of aspects and components with scores. Through interviews with the institutes management, scores were derived which were used to determine the capability of CDS-ZC in implementing the project.
- Reconnaissance field visits: in order to assess the ecological conditions in terms of soil, land uses and composition of species in the area, field visits were undertaken. In addition, field visits were undertaken to determine the mortality rate of the seedlings given the prevailing ecological conditions. This was deemed to be the most important indicator of ecological sustainability.
- Consultation and interviews: this is another important method that was employed to assess the willingness of the community to participate in the project. Interviews and consultations were done with CDS-ZS and Zongoene communities.

4.3 Economic sustainability

Economic sustainability of the reforestation project was assessed on two aspects mainly project viability and funding/financing mechanisms. Project viability was determined based on the project's projected costs and benefits stream over a 50 years period. Fifty (50) years was selected as the average period as assessment indicated that the old mangroves in the Limpopo are approximately 100 years old. In addition 50 years was based on Alongi's (2002) determination of the growth stage of mangroves. The estimated coverage of the reforestation program was estimated to be 50 hectares with 30 hectares already reforested by CDS-ZS.

The costs of reforestation were based on the past expenditures incurred by CDS as depicted in Table 16 below.

Table 16: Expenditure for mangrove reforestation project

Year	Budget (MZN)	Activities
2011	500,000.00	construction of drainage
2012	300,000.00	collection of seedlings, soil preparation and planting and monitoring
2013	550,000.00	seedling, soil preparation and planting and monitoring
2014	275,000.00	seedling, soil preparation and planting and monitoring

Based on the estimated 30 hectares already reforested and costs incurred, the average cost of replantation is calculated at MZN 54,167.00 per hectare. Thus, this value is used in NPV calculations. The following assumptions were made in projecting costs and benefits:

- The reforestation project will cover 20 hectares
- The project will take approximately 4 years to complete
- Monitoring will be undertaken for over 50 years
- Costs and benefits will increase by 7% annually
- Monitoring costs will be 10 percent of the total reforestation project budget
- Full benefits of the mangroves will be reached at maturity which is 15 years (Alongi, 2002). Therefore, from 1 to 10 years, the benefits will be accrued through carbon sinks, flood control and agricultural protection. The users' benefits (fuel wood, timber, construction material) will not be realized in the first 10 years.
- Discount rate is 5%

Based on the above assumption, annex 1 depicts the stream of costs and benefits and discounted values. NPV and Internal rate of Return (IRR) for the project are estimated at MZN 990 million and 236 per cent indicating that the project is highly economically sustainable.

Financing mechanism (funding) is another important component of economic sustainability. Projects that have robust and diverse financing mechanisms in place, are not susceptible to international financial uncertainties. Based on the scorecard, findings are that the project has various financing sources ranging from the government, and other funding partners notably NGOs, IUCN and USAID amongst others. In addition, over 80 per cent of the respondents from the community indicated that they would be willing to contribute through either cash or labor for the reforestation project.

However, consultations with the implementers reveal a disturbing financing situation where the project scored 25 percent on aspects of tools for revenue generation. It was evident that the project is reliant on external funding from both government and other funders (local and international). There are no mechanisms in place for the project to finance itself in future, for monitoring and reforestation purposes. Thus, the only aspect that the project performed satisfactorily concerns the diverse array of sources used to finance the reforestation projects. Areas of financing where the project performed dismally include aspects such as sources of income generation, initiatives to fund reforestation and monitoring and a legal framework to support the implementation of income generation for mangroves conservation. On this aspect, the project is financially unsustainable as it relies on external funding (local and international).

It is thus important that financing mechanisms mainly Payments for Ecosystem Services (PES) are investigated, designed and implemented to generate income for mangrove conservation. This practice will ensure that mangroves have adequate financial resources and rely less on external funding which could be less reliable.

4.4 Social sustainability

Social sustainability was assessed by determining the institutional capacity of CDS-ZS in implementing the project without external manpower and also the availability of resources in the institution. Additionally, the assessment entailed a situational analysis of economic activities undertaken in the proximity of the mangroves. An investigation was undertaken to determine the availability of economic activities that are accessible to members of the community in order to alleviate pressure on the mangroves. Most importantly, legal framework and enforcement was also evaluated. It is fundamental to highlight that the abovementioned factors (legal and enforcement, capacity of the implementing institution and the availability of economic activities) are all jointly important in determining the social sustainability of mangrove reforestation.

As evident from the fact that CDS-CZ has already reforested 30 hectares, the institutional sustainability score conforms its capacity to implement the project without external manpower support. CDS-ZS attained a score of 93 per cent for institutional capacity to implement the project. The only area in which the organization performed slightly lower relative to other components concerned the availability of resources to implement the project. In the main, the institution has an adequate manpower and skill mix to implement the project. Most importantly, the organization does not rely on external expertise for the implementation of the project. Thus based on the institutional capacity, the project is sufficiently sustainable for implementation without any external support.

In addition to institutional capacity there was a need to determine the overall capacity of the legal framework and law enforcement so as to ensure that upon project completion, anthropogenic mangroves degradation would be limited. Thus, a component of the scorecard was developed to inform issues relating to the legal framework and law enforcement. Aspects of the legal framework and law enforcement that were evaluated included the following:

- Presence of Policies and Acts at the national level to support reforestation
- Capacity for law enforcement
- Adequacy of resources to support enforcement of Acts and Policies
- Monitoring for enforcement

Based on the scorecard, the legal framework and law enforcement was assessed to be less adequate with a score of 47 per cent. In all aspects that were assessed, there were some deficiencies. For instance, investigation reveals that there is no monitoring for enforcement of the legal framework for mangrove protection. Additionally, there are no adequate resources to support the enforcement of legal frameworks for the protection of mangrove ecosystems in the region. Therefore, based on the findings, there is a danger that reforested mangroves could be degraded at a later stage. Thus, the future sustainability of the project is questionable as enforcement and monitoring to determine use of mangroves forests is inadequate. The findings of this assignment were supported by comments raised by the stakeholders at the inception workshop which indicated that the community in many instance use mangroves unsustainably. Furthermore, the stakeholders noted that their role in management of the mangrove ecosystem is not clear which results in mismanagement of the forests. Subsequently, stakeholders (members of the community) highlighted that the government has invested heavily in mangroves reforestation in Maputo. However, due to issues of lack of monitoring and enforcement, the mangrove has already been degraded.

Furthermore, assessment was undertaken to determine availability of existing and proposed economic activities to alleviate pressure from the mangroves. In order to alleviate pressure from the mangroves, CDS constructed aquacultures for the community to produce and sell fish and crabs. However, the aquacultures have been destroyed by previous floods and there is need for rehabilitation. Additionally, CDS has invested heavily in drainage systems to improve agricultural yields from the fields in the proximity to mangroves. Furthermore, CDS has also planted some timber tree species in Zongoene to abate pressure from mangroves as a source of timber. Generally, there are some good initiatives that have been implemented to alleviate pressure from the mangroves.

4.5 Ecological sustainability

Assessment of the ecological sustainability of the mangrove reforestation project involves determining whether the environmental/ecological conditions would accommodate replanting of the mangrove seedlings. Thus, the assessment involved field visits and consultation with the project implementers as a way of gauging ecological dynamics in the project site area. Furthermore, land uses analysis was undertaken to determine how land uses could have affected the area previously occupied by mangrove forests.

Reconnaissance field visits and consultation with the project implementers revealed the following fundamental aspects of the area:

- Post-flooding of 2000 culminated in extensive charcoal production due to prolific dead mangrove trees. In fact, this resulted in artificial dunes with an elevation of approximately 60 meters (Picture 3). The change in topography affected water flows as water could not reach the dunes which in turn were used as a kiln. The total surface area of the replantation area that has been affected by charcoal production is approximately 10% which translates into 2 hectares.
- Additionally, charcoal producing activities in the mangrove ecosystem has resulted in increased charcoal matter in the soils. Various studies have been conducted on the effects of increased charcoal content in soils (Kolb et al, 2009; Zackrisson et al, 1996; Warnock et al, 2007; Nigussie and Kissi, 2011). Consistently, these studies were in agreement on the following aspects:
    a. Charcoal increased Nitrogen uptake by seedlings for up to 100 years
    b. Soils exposed to charcoal production have a high organic content, pH and nutrient availability for plants.
    c. Charcoal provides a recalcitrant which is a food source for microbes.
    d. Charcoal's high porosity provides a favorable habitat for soil microflora which thus alters the predation rates by soil micro fauna.

Thus field surveys revealed the following on the replanted site:

- An accelerated growth of mangrove seedlings that have been replanted in 2010-2011.
- An increased population of crabs in the area which are feeding on micro fauna and microflora (mainly mangrove seedlings).

Picture 3: An abandoned Kiln site

Picture 2: Mangrove stems and charcoal production

Picture 4: Mangrove seedling protected from crabs by reed stem

Due to the prolific presence of various crabs in the replanted area, it is reported that the seedling mortality rate was approximately 60-70 per cent prior to the use of innovative reed stems. However, this mortality rate has been reduced to 10-20% by protecting the seedling with the reed stem (Picture 4).

Another factor worth investigating which affects the sustainability of the mangrove reforestation project in the area is flood events. Record floods in the area have a return period of approximately 30 years. Therefore, this could cause the same damage as the past floods.

Thus, from an ecological point of view, the environment is ecologically suitable for the mangrove replantation. This is also supported by the fact that the area that has been replanted in 2010 is now fully established with mangrove trees to a height of approximately 2 meters and above (Picture 5).

Picture 5: Replanted mangroves in 2010

4.6 Conclusions

The Limpopo Estuary mangroves reforestation project was assessed to determine its sustainability on the basis of economic, social and ecological principles. Economic sustainability entailed determining the viability of the project by calculating NPV and IRR based on streams of costs and benefits over time. Economically, the project is highly viable as the NPV is positive and IRR is high at 236 per cent. The implication of these indicators is that the discounted benefits are far greater than the cost of undertaking the reforestation project. Social sustainability was assessed based on the capacity of the CDS to implement the project and the availability of manpower and skill within the CDS. Based on the derived institutional scorecard, CDS fared exceptionally well in implementing the project. This is evident by the successful reforestation of 30 hectares since 2010. However, there were other aspects where the project was deemed unsustainable. For instance, the project is heavily dependent on external funding even though the funding mix is adequate and comprehensive. Additionally, there are no policies and no legal framework in place for the project to implement tools and mechanisms to enable the project to internally generate revenue for future conservation work programs. In addition, the scorecard highlighted that the project suffers from a lack of law enforcement and monitoring in order to ensure that the reforested mangroves are not degraded and depleted again.

Ecological sustainability was assessed by determining the land uses, species composition, soils and survival rate of the seedlings. Field visits indicated that though land use has not changed, the reforested area was temporarily used for the production of charcoal due to the high abundance of dead trees after the year 2000 floods. This activity has affected topography as there are some elevated patches where there were kilns. This affects the hydrological flow and seedling growth. In addition, charcoal production has resulted in an increase in the charcoal content of the soil. Various studies have assessed the ecological benefits associated with a relatively high charcoal content in soil (Kolb et al, 2009; Zackrisson et al, 1996; Warnock et al, 2007; Nigussie ad Kissi, 2011). For instance, it is reported that

Charcoal's high porosity provides favorable habitats for soil microflora which thus alters the predation rates by soil micro fauna. This could be a possible explanation for the prolific population of crabs in the reforestation areas. The impact of an increased number of crabs has significantly affected seedling survival rate which was estimated at 20 per cent prior to the implementation of the innovative reed stem protection method. This method has improved survival rate from 20 per cent to over 60 per cent. Thus, based on an overall survival rate of greater than 60 per cent, the project is ecologically sustainable.

5. Summary of findings

The following summarizes the findings emanating from the ecological structure of mangroves, economic valuation of the mangroves and an overall assessment of the sustainability of mangroves reforestation.

- Mangroves in the Limpopo estuary are multifunctional providing multiple products, functions and services that are of high ecological and economic value. They support the majority of local communities through varies functions and provide a source of food and energy.
- These products, functions and services vary both spatially and temporally. For instance the function of being a carbon sink is beneficial globally while regulation of microclimate is of local to regional importance. Temporally, the functions also vary from seasonal to yearly. For instance, the protective function against storms and high tidal waves is seasonal.
- The economic value of mangrove is estimated at MZN 424 million, with the direct use value and indirect use value constituting MZN 357 million and MZN 67 million respectively.
- This has sustainability implications, it implies that there is a high use of mangrove products and less use of functions and services offered by the mangroves.
- The majority of community members consulted (80 per cent) living in close proximity to the Limpopo estuary mangroves indicated that they would be WTP for its conservation through reforestation.
- Of those who revealed that they would be WTP for mangrove reforestation project, 84 per cent indicated that they would be WTP through labor while 16 per cent indicated that they would prefer paying in cash.
- For those WTP through labor, their WTP based on value of their labor was estimated at MZN 650 per month (10 working days per month) while for those who indicated cash payments their WTP was estimated at MNZ 70 per month.
- Assessment of the economic sustainability of the reforestation project revealed a high positive NPV and IRR of MZN 599 million and 236 per cent based on a 50 years period.
- In terms of funding mechanisms the project has a solid mixed funding stream. However, the project lacked internal funding mechanisms in terms of both the necessary tools and mechanisms for revenue generation.
- There are both policies and a legal framework that are needed to enhance the project in order to generate revenue required for conservation activities such as monitoring.
- Socially, the project is sustainable based on the institutional capacity scorecard.
- Non-anthropogenic activities particularly floods have catastrophic impacts on mangroves and could worsen with climate change.

- In terms of monitoring and law enforcement, its score was estimated at 47 per cent implying that the newly established plantation could be exposed to unsustainable practices in the future. Hence, monitoring needs to be improved.

6. Recommendations

Based on the findings of this assignment, the following recommendations were made:

- Efforts must be put in place to ensure that members of the community maximize the benefits from indirect uses of the mangroves. This will ensure that the sustainability of mangroves utilization is enhanced as indirect benefits do not result in harvesting of mangrove products. This can be done through improving aquaculture, apiculture, ecotourism and agriculture practices.
- Analysis reveals that the reforestation project has virtually no mechanism for the generation of internal revenue. This basically implies that if the funders pull out, the project could be seriously affected. It is thus important that for project continuity, tools for revenue generation be designed and implemented. One of the important ways in which mangroves can generate revenue for monitoring and law enforcement is through Payment for Ecosystem Services. There are many forms of Payment for Ecosystem Services such as charging for using products, the sale of sustainably harvested products and timber, REDD+ programs. It is thus important that Payments for Ecosystem Services are comprehensively designed and implemented for monitoring and enforcement purposes. This thus calls for further studies for development of PES framework and guidelines for implementation PES best model.
- Monitoring and law enforcement is found to be lacking when it comes to the utilization of mangrove products. It is thus pertinent that efforts are geared towards improving monitoring and law enforcement.
- One way to improve monitoring and management of the mangrove resource is through co-management where members of the community are actively involved in mangrove management. Co-management is a double-edge sword in terms of benefits as the community members will be part of the decision making process and will also realize improved benefits and household income from better managed mangroves.
- It is recommended that in-depth assessment be undertaken to identify the optimal co-management model that can be implemented for management of Limpopo mangrove ecosystem and guidelines be developed to guide its implementation. The guidelines should elaborate on roles and responsibilities of each party, cost and benefits sharing formula.
- Mangroves have considerable potential for eco-tourism activities which currently are non-existent. It is thus important for communities to be encouraged to venture into these activities. Thus, furthermore work is required on assessment of potential ecotourism projects, their feasibility, viability and development of management plans (entailing business plans). Additionally, it is pertinent that assessment of current climate in terms of policies and legal framework to support such business ventures be undertaken.
- There is a need to design and implement economic activities and policy frameworks for diversifying pressure away from the mangroves. Potential policies include subsidies on natural gas. Therefore, there is need to undertake a thorough assessment on

economic activities and supporting policies that can be implemented with emphasis on cost benefit analysis

- Though members of the communities are highly knowledgeable about the economic benefits of the mangroves, they lack information on the actual values and economic contribution of mangroves to their household income. Therefore efforts must be geared towards information dissemination on the total economic value of mangroves and the contribution they make to household income.
- Floods have disastrous impacts on mangrove ecosystems as evident from the year 2000 floods. It is thus recommended that an integrated Limpopo river basin management system is developed in cooperation with the Limpopo Riparian states/countries. This management system should develop guidelines on dams and flood control in the Limpopo River.

7. References

Alongi, D. M. (2002) Present state and future of the World's mangrove forests. Environmental Conservation 29 (3): 331-349.

Barbosa, F. Cuambe, C., Bandeira, S. (2001). Status and distribution of mangroves in Mozambique, South African Journal Botany; Vol. 67, pp. 393 – 398.

Blaber, S.J (2007). Mangroves and fishes: Issues of diversity, dependence, and dogma. *Bull. Mar. Sci*. *80*, 457–472.

Cannicci S., Bartolini F., Dahdouh-Guebas F., Fratini S., Litulo C., Macia A., Mrabu E. J., Penha-Lopes G. & Paula J. 2009. Effects of urban wastewater on crab and mollusc assemblages in equatorial and subtropical mangroves of East Africa. Estuarine, Coastal and Shelf Science 84 (2009) 305–317

De Grave S. & Barnes D. K. A. 2001. Ecology of tropical hermit crabs (Crustacea Decapoda) at Quirimba Island, Mozambique: A multivariate assemblages perspective. Tropical Zoology 14: 179 – 209

Fatoyinbo, T. E., M. Simard, R. A. Washington-Allen, and H. H. Shugart (2008), Landscape-scale extent, height, biomass, and carbon estimation of Mozambique's mangrove forests with Landsat ETM+ and Shuttle Radar Topography Mission elevation data, J. Geophys. Res., 113, G02S06, doi: 10.1029/2007JG000551.

Giri. C., Ochieng, E., Tieszen, L.L., Zhu, Z., Singh, A., Loveland, T., Masek, J and Duke, N (2010). Status and distribution of mangrove forests of the world using earth observation satellite data. Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2010).

Kolb, E. S., Fermanich, J. K., and Dornbush, E. M (2009). Effect of charcoal quantity on microbial biomass and activity in temperate soils. SSSAJ. Volume 73:1173-1181

Lieth, H., and R. H. Whitaker (1975), Primary Productivity of the Biosphere, Springer, New York.

Ministerio para o Coordenacao da Accao Ambiental (MICOA). 1997. Strategy and areas of action for the conservation of biological diversity in Mozambique. 2nd Draft. Maputo. Mozambique.
http://www.bipindicators.net/LinkClick.aspx?fileticket=bQNpCYkyZnY%3D&tabid=178

Nigussie, A and Kissi, E (2011). Effects of charcoal production on soil properties. Southwestern Ethopia. Middle-east Journal of Scientific Research 9(6):807-813

Piao, S., J. Fang, B. Zhu, and K. Tan (2005), Forest biomass carbon stocks in China over the past 2 decades: Estimation based on integrated inventory and satellite data, J. Geophys. Res., 110, G01006, doi: 10.1029/ 2005JG000014

Ronnback, P. 2001, Mangroves and seafood production: the ecological economics of sustainability, Doctoral Thesis in Systems Ecology, Stockholm University.

Salem, E. M and Mercer, E.D (2012) The Economic Value of Mangroves: A Meta-Analysis. Sustainability *4*, 359-383

Samoilys M., Maina G. W., Church J., Mibei B., Monjane M., Shah A., Mutta D. & Pabari M. 2013. Situation analysis for Mangroves for the Future: Understanding the resilience of coastal systems

Silva, A, Lobo, A., Maduela, A., dos Santos, I., Manuel Menomussanga, M., Tamela, P (2014). Mapping of mangrove vegetation communities and degraded areas in the Limpopo Basin Estuary.

Sitoe, A.A., Mandlate C, J. L and Guedes S.B. (2014). Biomass and carbon stocks of Sofala Bay Mangroves Forests. Forests 2014:5, 1967-1981.

Spalding, M., Kainuma, M., Collins, L (2010) World Atlas of mangroves: A collaborative project of ITTO, ISME, FAO, UNEP-WCMC, UNSCO-MAB, UNU-INWEH and TNC. London (UK): Earthscan London. 319pp

Spurgeon, J (2002). Rehabilitation, Conservation and Sustainable Utilization of Mangroves in Egypt- Socio-economic assessment and economic valuation of Egypt's mangroves

UNEP/FAO/PAP: Xai-Xai District Coastal Area Management Strategy. East African Regional Seas Technical Reports Series No. 2. Split, Croatia, 1998, pp-xvi+84.

USAID (2010) competitiveness of the Mozambique fishery sector. USAID.

Warnock, D.D., J. Lehmann, T.W. Kuyper, and M.C. Rillig. 2007. Mycorrhizal responses to biochar in soil: Concepts and mechanisms. Plant Soil 300:9–20.

Zackrisson, O., M.C. Nilsson, and D.A. Wardle. 1996. Key ecological function of charcoal from wildfire in the boreal forest. Oikos 77:10–19.

ANNEX 1

year	Cost	project benefits	Dc	db
0	270,835.00	0	270,835.00	-
1	289,793.45	819,780.00	275,993.76	780,742.86
2	310,078.99	1229670	281,250.79	1,115,346.94
3	331,784.52	1,639,560.00	286,607.94	1,416,313.57
4	33,178.45	1,754,329.20	27,295.99	1,443,290.97
5	35,500.94	1,877,132.24	27,815.92	1,470,782.23
6	37,986.01	2,008,531.50	28,345.75	1,498,797.13
7	40,645.03	5,144,084.00	28,885.66	3,655,804.46
8	43,490.18	7,716,126.00	29,435.87	5,222,577.80
9	46,534.50	14,660,639.40	29,996.55	9,450,378.87
10	49,791.91	25,720,420.00	30,567.91	15,790,106.72
11	53,277.34	27,520,849.40	31,150.16	16,090,870.66
12	57,006.76	29,447,308.86	31,743.50	16,397,363.44
13	60,997.23	31,508,620.48	32,348.13	16,709,694.17
14	65,267.04	33,714,223.91	32,964.29	17,027,974.06
15	69,835.73	36,074,219.59	33,592.18	17,352,316.42
16	74,724.23	38,599,414.96	34,232.03	17,682,836.73
17	79,954.93	41,301,374.00	34,884.07	18,019,652.67
18	85,551.77	44,192,470.18	35,548.53	18,362,884.15
19	91,540.40	47,285,943.10	36,225.64	18,712,653.37
20	97,948.22	50,595,959.11	36,915.66	19,069,084.87
21	104,804.60	54,137,676.25	37,618.81	19,432,305.53
22	112,140.92	57,927,313.59	38,335.36	19,802,444.68
23	119,990.79	61,982,225.54	39,065.56	20,179,634.11
24	128,390.14	66,320,981.33	39,809.66	20,564,008.09

25	137,377.45	70,963,450.02	40,567.94	20,955,703.48
26	146,993.87	75,930,891.52	41,340.66	21,354,859.74
27	157,283.44	81,246,053.93	42,128.11	21,761,618.97
28	168,293.28	86,933,277.70	42,930.55	22,176,126.00
29	180,073.81	93,018,607.14	43,748.27	22,598,528.40
30	192,678.98	99,529,909.64	44,581.57	23,028,976.56
31	206,166.51	106,497,003.32	45,430.74	23,467,623.73
32	220,598.17	113,951,793.55	46,296.09	23,914,626.09
33	236,040.04	121,928,419.10	47,177.92	24,370,142.77
34	252,562.84	130,463,408.44	48,076.55	24,834,335.97
35	270,242.24	139,595,847.03	48,992.29	25,307,370.94
36	289,159.19	149,367,556.32	49,925.48	25,789,416.10
37	309,400.34	159,823,285.26	50,876.44	26,280,643.08
38	331,058.36	171,010,915.23	51,845.52	26,781,226.75
39	354,232.45	182,981,679.29	52,833.05	27,291,345.36
40	379,028.72	195,790,396.84	53,839.39	27,811,180.51
41	405,560.73	209,495,724.62	54,864.91	28,340,917.28
42	433,949.98	224,160,425.35	55,909.95	28,880,744.27
43	464,326.48	239,851,655.12	56,974.90	29,430,853.69
44	496,829.33	256,641,270.98	58,060.14	29,991,441.38
45	531,607.39	274,606,159.95	59,166.05	30,562,706.93
46	568,819.90	293,828,591.14	60,293.02	31,144,853.73
47	608,637.30	314,396,592.53	61,441.46	31,738,089.04
48	651,241.91	336,404,354.00	62,611.77	32,342,624.07
49	696,828.84	359,952,658.78	63,804.38	32,958,674.05
50	745,606.86	385,149,344.90	65,019.70	33,586,458.32
		Total	3,160,201.56	993,948,951.70
			NPV	990,788,750.14

ANNEX 2: Institutional capacity scorecard

Institutional capacity for sustainability of the mangroves reforestation				
Institutional capacity for sustainability of the mangroves reforestation	None (0)	some (1)	a few(2)	Full(3)
Manpower is available to conduct mangroves reforestation				
There is adequate skill mix to implement the project				
There is adequate resource to implement the project				
The extent to which the institution will rely on external skills to implement the project				
Capacity of the institution to monitor and evaluate the project				
Legal framework and enforcement	None (0)	some (1)	a few(2)	Full(3)
There are policies in place at the national level to support mangrove reforestation				
There are Acts in place at the national level to support mangroves reforestation				
There is capacity for enforcement of the legal framework for protection of mangroves				
There are adequate resources to support enforcement of legal framework for protection of mangroves				
There is adequate monitoring for enforcement of legal framework for mangrove protection				

Tools for revenue generation	No (0)	Partially(1)	Complete(2)	Operational (3)
The project will have sufficient funds to finance mangrove reforestation				
The project has a diverse source of funding to finance mangrove reforestation				
The project has source of income generation initiatives to fund the reforestation				
There are legal framework that allow the project to generate income for mangrove conservation				

ANNEX 3: Economic Valuation Questionnaire

Mangroves ecosystem valuation

				Official Use
	Serial Number		**Numeration Area.**	
	Name of enumerator			

				Official Use
1	Respondent's education	Tertiary		
		Secondary		
		Primary		
2	Respondent employment status	formally employed		
		Informally employed		
		employed		
3	employment sector	construction		
		Agriculture		
		tourism		
		Government		

		Other	
4	If unemployed, state source of Income		
5	Please indicate salary bracket (MZN)	0-500	
		501-1000	
		1000-2000	
		2000-4000	
		5000 +	
6	Do you harvest mangrove products	Yes	
		No	
7	If Yes, state products harvested		
		fruits	
		Vegetables	
		Traditional medicines	
		Timber	
		Fish	
		Crustaceans	
8	of the products, select the three most important for people's livelihood in your area		

9	State frequency of harvest	
10	State quantity harvested on weekly basis	
11	Indicate products that are harvested for consumption	
12	Indicate products that are harvested for sale	
13	kindly indicate the market prices for the products that are sold	

14	Does the respondent purchase mangrove products	Yes No	☐ ☐
15	If yes which ones		
16	Kindly indicate the price of mangroves products that you purchase		
17	Are mangrove essential in your production processes	**Yes** **No**	☐ ☐
18	If Yes, which production processes require mangroves functions		

19	State which mangrove functions are essential in production processes
20	How does the change in mangroves attributes affect the production of goods and services
21	If you were to rank relationship between mangroves attributes and production of goods and service how would you rank it

high	**a change in mangrove affect production significantly**	☐
medium	**a change in mangrove affect production moderately**	☐
Low	**a change in mangroves affect production marginally**	☐

22 What is the status of the mangroves ecosystem in the Limpopo

Quality improving ☐

Degradation ☐

No change ☐

23 What are the major threats to mangrove conservation in your area Please rank

- tourism development ☐
- Settlement expansion ☐
- overfishing ☐
- overharvesting ☐
- Inadequate policy env. ☐
- climate change ☐
- Deforestation ☐
- other ☐

24 *Would you be willing to participate in mangrove reforestation*

Yes ☐

No ☐

23 If Yes how would you be willing to participate in Mangrove reforestation

- contribution in income ☐
- contribution through labor ☐
- any other ☐

24	if contribution in income, how much would you be willing to contribute
25	If through labor, how many months
26	In your view what are current and possible threats to mangroves degradation
27	what are possible recommendations for improving mangroves status
	Thank you very much for your time